

City Document.—No. 85.

CITY OF BOSTON.



REPORT ✓

OF THE

Joint Standing Committee on Water,

TOGETHER WITH THE

REPORT OF THE CITY ENGINEER

IN REPLY TO

ORDERS OF THE CITY COUNCIL PERTAINING TO AN IN-
CREASED SUPPLY OF WATER FROM THE COCHIT-
UATE AND MYSTIC LAKES COMBINED,
AND AN ADDITIONAL SUPPLY FROM

CHARLES RIVER.

REPORT OF COMMITTEE ON WATER.

CITY OF BOSTON.

IN COMMON COUNCIL, 26th October, 1874.

The Joint Standing Committee on Water Department, who were requested —

First — To ascertain and report whether the present source of our water supply from Lake Cochituate and Mystic lake, combined, can be so utilized as to give an adequate water supply to the city in a season of drought, how great that supply would be, for how many years it would be adequate, and the expense of procuring it;

Second — To examine the Charles river and report upon its availability as a source of supply, and the expense of conveying the waters to Chestnut-hill reservoir, —

Beg leave to submit herewith the reports of the City Engineer and his assistants, giving full and complete information upon all the points covered by the orders of the City Council.

The yield in a dry year from the Cochituate and Mystic sources, after making improvements and additions to the works at an estimated cost of \$1,342,032, is estimated at 33,000,000 gallons daily. Assuming from past experience that the future increase of consumption will be at the rate of seven per cent. yearly, the supply would be fully used in 1877. The yield in an ordinary year from the two sources would be from thirty-six to thirty-nine millions of gallons daily, which would meet the estimated consumption in 1878 or 1879.

Five schemes of works for obtaining a supply of fifty million gallons daily from Charles river are given, with esti-

mates of the cost of each. (See pp. 33 to 37 Engineer's report.) The report of the Commission (which will be submitted in a few days) upon the purity of the different sources of supply will be of great value in determining the point where it would be safe to take a supply from Charles river.

In considering this question of a permanent water supply it should be borne in mind that the plans for the Sudbury-river scheme have been prepared at great expense, and that the work can be prosecuted energetically and without interruption as soon as the necessary authority to take lands is given. If the authority asked for had been granted last year, at least a third of the work on the proposed line of the Sudbury conduit would have been completed. If any other scheme is adopted, it will take another year to obtain the necessary legislation, and a long additional delay for the preparation of new plans.

In view of the unusually low state of the water both in the Cochituate and Mystic basins, caused by the absence of the ordinary fall rains and the great increase in the number of water-takers during the present year (nearly two thousand on the Cochituate service alone), making the consumption at the present time twenty million gallons per diem from that source of supply, your committee again urge upon the City Council the importance of immediate action to provide an additional supply of water adequate to meet the wants of the city. The water in the Chestnut-hill reservoirs this morning was five feet below high-water level, being the lowest point ever reached; and the water in the Cochituate lake was six feet seven inches below high-water mark. Unless we have copious rains during the next few days, the lake will be so reduced as to require the aid of steam pumps to raise the water to the flow line of the conduit, or the opening of the gates from the temporary connection made in 1872 with Sudbury river. The Cochituate Water Board decline to adopt the latter alternative without authority from

the City Council, because of the personal liability which would follow such action. It will be remembered that the property of the members of the Water Board of 1872 is now under attachment for a similar taking of the Sudbury water during the drought of 1872. Your committee are informed that Mystic lake is, at the present time, about three feet six inches lower than at this date last year.

It will be noticed in the report of Mr. Fteley, that a plan is presented for diverting the water of Pegan brook, in the town of Natick. The pollution of Lake Cochituate from this source, although inconsiderable, has always been a source of anxiety to the Water Board, and, for reasons set forth by the State Board of Health and by Mr. Fteley, it would seem desirable to remove this pollution at once. A portion of the expense should, however, be borne by the town of Natick, and your committee would recommend the passage of the accompanying order authorizing the Mayor to petition the Legislature, at its next session, for authority to be given to the city of Boston and the town of Natick to construct a sewer for that purpose.

The committee would also call attention to the fact that the conduit from the lake has been for the past month run under a pressure to keep up the supply, and must be closed for a short time during the next few days for the purpose of making necessary repairs before cold weather.

In conclusion, the committee urge upon citizens generally the necessity of using water with great caution, that the supply may be eked out until heavy rainfalls again fill the lake.

For the Committee,

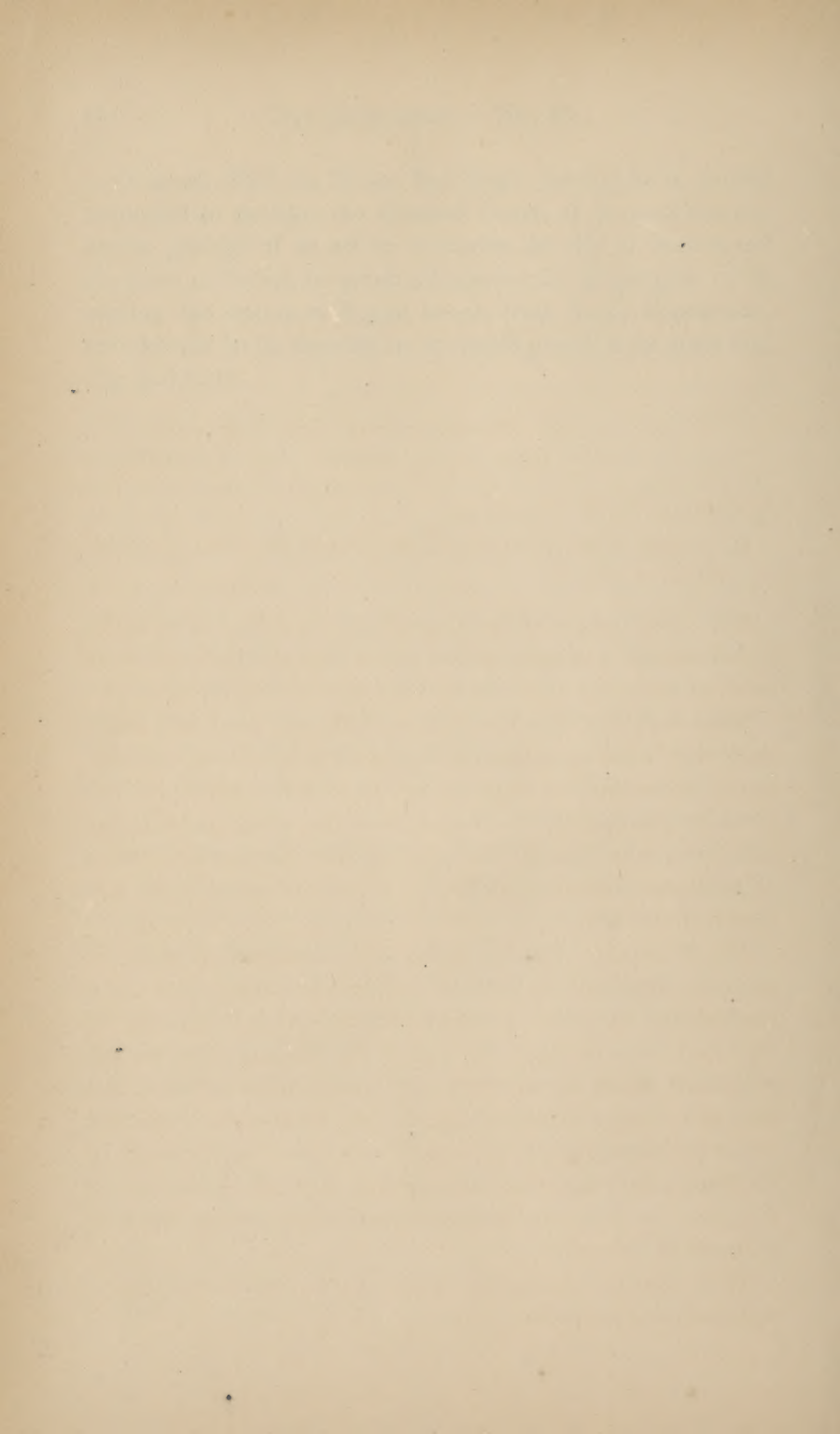
S. B. STEBBINS,

Chairman on the part of the Board of Aldermen.

FREDERICK PEASE,

Chairman on the part of Common Council.

Ordered, That his Honor the Mayor be and he is hereby requested to petition the General Court, at its next session, for the passage of an act to authorize the city of Boston and the town of Natick to construct a sewer for the purpose of diverting the waters of Pegan brook from Lake Cochituate; the expense to be assessed in equitable proportions upon said city and town.



REPORT OF CITY ENGINEER.

OFFICE OF THE CITY ENGINEER,
CITY HALL, BOSTON, Oct. 10, 1874.

ALDERMAN S. B. STEBBINS,

Chairman Joint Standing Committee on the Water Department: —

SIR: The orders of the City Council relating to an additional supply of water, passed June 15 and June 29, were referred to me by your committee about three months ago.

Since then my time has been so fully occupied with other work that it has been impossible for me to give that attention to the investigations required by the orders which their importance demanded, therefore I have had them made, under the direction of Mr. A. Fteley, Resident Engineer in charge of additional supply, and Mr. D. W. Cunningham, First Assistant under him.

Mr. Fteley has had in charge the examinations made to ascertain what may be done to increase the supply from Lake Cochituate, and to determine the value and capacity of Charles river as a source of supply for this city, also the experiments made to ascertain the volume of overflow at the dam and conduit of Mystic lake. Mr. Cunningham has had under his direction the surveys of the Mystic valley made to determine the capacity of available storage, its character and cost, and the probable available yield of the whole valley in a season of drought.

Their reports, which give the results of very careful investigations, are appended.

Before discussing the subjects of the orders, I desire to call attention to two positions which have been maintained in former reports upon the matter of additional water supply.

The first is, that the true value of a source of supply is measured by its yield in seasons of drought.

The second, that in this region it is not safe to assume that more than twelve inches in depth of rain can be collected in a very dry year from drainage areas of the character of those with which we are dealing.

The first proposition seems self-evident; it certainly has been sufficiently proved by experience. In Appendix I, City Doc. No. 38, 1874, will be found much valuable testimony on this point. It is there shown that some eighteen or twenty cities and towns in England, depending upon supplies from small rivers requiring the storage of water for use in the summer season, were caused great inconvenience or distress by the drought of 1868. In some instances the supply for manufacturing uses was entirely cut off, and in one case the consumption was limited to seven gallons per head per day, the use of water for baths, etc., being prohibited.

The capacities of the various sources had originally been very much overestimated, — the estimates being based upon *average* rainfall and percentages of yield, instead of upon minimum quantities.

Many of these cities were favorably circumstanced, and did not suffer so great distress as would cities in this country under a like failure of supply.

In England it is the custom to reserve a certain portion of the flow of the rivers, as one-third or one-fourth, for the use of the mills, and by arrangement with the mill-owners some of the cities kept up a partial supply to the inhabitants by drawing upon this reserved portion.

The testimony of engineers before the royal commission of 1868 was very direct and emphatic on this question. Mr. John Taylor, in a report to the commission, uses this lan-

guage: "The general conclusions to be drawn from the data I have given in the preceding pages respecting the largest gravitation water supplies in this country, are as follows:—

"That none of the works alluded to have completely fulfilled the anticipated results.

"Manchester and Glasgow are favorable examples of gravitation works, but exhibit signs of deficiency when tested for cycles of dry years; and of the *five* large towns alluded to, *four* have already erected, or are erecting, pumping-works in aid of the gravitation supplies. . . .

"Thus it appears that basing calculations on *average* falls of rain is erroneous; the *minimum* quantities only should be depended upon. . . .

"The axiom in mechanics, that the strength of a beam is the strength of its weakest part, applies also to gravitation water works, their real strength or power of supply being only the *minimum quantity they may be reduced to*."

The experience of Boston and other American cities in 1871, — a year of partial drouth, — and of some English cities this season, is corroborative of the accuracy of the above statements.

It should be borne in mind that it is not necessary for the drought to actually occur before a city shall suffer from the evil effects of overtaxing its source of water supply, as the mere feeling in a community that the supply is liable to run short, under any probable circumstances, works great injury to its interests, more particularly to the development of its manufactures.

For the past few years the Cochituate Water Board has felt compelled to deny the use of water for many purposes, especially for motive power, which use not only would have added to the general prosperity of the city, but also would have largely increased the water revenue.

The second position has been discussed in City Doc. No.

29, 1873; pages 9-12, and City Doc. No. 38, 1874, pages 4-5.

On page 36 of the last annual report of the Water Board will be found a table giving the percentages of rainfall which have been collected from the Cochituate district for a long term of years. It has been stated that those given for a few years preceding 1863 are considerably too large, owing to the use of an inaccurate method of obtaining the volume of flow in the conduit; hence they will not be considered.

While the percentage sometimes falls as low as 33 and 35, the average from 1862 to 1873, a term of eleven years, is 40, and careful experiments at other points have verified these figures. The result is for years of *average* rainfall; it would seem, therefore, a well-established fact that the percentage of rainfall collectable in a *dry* year cannot be safely assumed as *greater* than 40.

The rain records of Boston, Cambridge, Lowell, and other places, show that in a season of great drought the rainfall is not more than 30 inches. Thus in 1846 the rainfall

In Boston was 29.95 inches.

“ Waltham “ 26.90 “

“ Lowell “ 28.03 “

“ Cambridge “ 30.37 “

“ Providence “ 30.51 “

The rain record of Lowell shows the following years of small rainfall, during a term of twenty-two years previous to 1847:—

In 1825 the rainfall at Lowell was 28.46 inches.

“ 1826 “ “ “ “ “ 32.49 “

“ 1834 “ “ “ “ “ 31.78 “

“ 1835 “ “ “ “ “ 32.42 “

“ 1836 “ “ “ “ “ 35.53 “

“ 1837 “ “ “ “ “ 30.86 “

In 1838	the rainfall at Lowell	was	37.52	inches.
" 1839	" " " "	"	38.21	"
" 1840	" " " "	"	38.70	"
" 1846	" " " "	"	28.03	"

The record of Providence gives the following consecutive series of dry years : —

In 1832	the rainfall at Providence	was	39.46	inches.
" 1833	" " " "	"	33.44	"
" 1834	" " " "	"	41.92	"
" 1835	" " " "	"	30.96	"
" 1836	" " " "	"	37.87	"
" 1837	" " " "	"	31.62	"
" 1838	" " " "	"	37.88	"
" 1839	" " " "	"	36.75	"

In 1822	the rainfall in Boston	was	27.20	inches.
" 1828	" " " "	"	32.41	"
" 1837	" " " "	"	33.52	"

It will be seen that a rainfall of from 27 to 33 inches is no uncommon occurrence, and that cycles of from two to five dry years do have place. It will also be noticed that a year of very low rainfall may be preceded by a number of years of drought ; thus, the low rainfall of 1837 in Lowell was preceded by three years in which the average rainfall was only 33.24 inches.

If from a rainfall of 30 inches 40 per cent. may be collected, there will be 12 inches available for a supply. This assumes that the losses from evaporation, vegetable absorption, etc., are no greater in a dry than in an average year.

In 1871, with a rainfall of about 42 inches, 13 inches (31 per cent.) were collected from the Mystic district.* (See Mr. Fteley's report, Appendix C.)

* The rainfall for this district has been taken at the average of the records for 1871, of Cambridge, Waltham, and Boston. If the Cambridge record alone be assumed as the more likely to be characteristic of the district, then the percentage will be 31 8-10.

On the Cochituate district the rainfall was 45.4 inches, of which a little over 33 per cent. was collected; should the same percentage obtain with a rainfall of 30 inches, the equivalent for the quantity available for a supply would be 10 inches only.

With such facts before us, it will not be wise to assume that more than 12 inches of rain can be collected for use in a season of great drought.

The following estimates of the quantity of water which the various water-sheds herein considered will yield, are for a very dry year, as required by the terms of the order of June 15. The average yield for a long series of years will usually be about one-third greater, but will vary very widely from year to year, and will be largely dependent upon the quantity of storage.

LAKE COCHITUATE.

In 1861, Dudley pond was connected with Lake Cochituate by an 18-inch pipe laid through the dividing ridge, and an area of about 544 acres was thus united to the watershed of the lake, and an area of 81 acres to its water-surface.

These areas are not used in computing the tables of available yield of the lake district given in the annual report, because the overflow is carried to the Sudbury river by an independent channel, and no measurement is made of it, and because it has not drawn upon every year; on the other hand, no deduction is made from the water-shed for water-surfaces.

In determining the yield in a season of drought, however, it is necessary that Dudley pond and its water-shed should be taken into account.

The total area from which the Cochituate supply is derived is:—

Area of the lake district	.	.	12,077 acres.
“ “ Dudley pond district	.	.	544 “
Total	.	.	12,621 “

REPORT OF CITY ENGINEER.

The area of water-surfaces, when the lake and ponds are full, is : —

Area of Lake Cochituate	.	.	.	801 acres.
“ Dug pond	.	.	.	45 “
“ Dudley pond	.	.	.	81 “
“ Shakum and Gleason's ponds	.	.	.	104 “
				——— “
Total	.	.	.	1,031 “

Area of water-shed exclusive of water-surfaces 11,590 acres.

In a season of drought the ponds will be drawn down much below high-water level, and, judging from the experience of 1871, will not present a water-surface exceeding 800 acres, as an average. In such a season, therefore, the available water-shed will be about 11,820 acres, or 18.47 square miles.

The available storage capacity is as follows : —

Lake Cochituate	.	.	.	2,000,000,000 galls.
Dug pond	.	.	.	150,000,000 “
Dudley pond	.	.	.	250,500,000 “
				——— “
Total	.	.	.	2,400,000,000 “

The following calculations will give the minimum daily supply for a year. Twelve inches in depth upon 18.47 square miles = 10,552,000 gallons per day.

To make this available there is required a storage capacity of 1,266,240,000 gallons. The actual storage capacity is in excess of this by 1,133,760,000 gallons, and will yield a daily supply of 3,100,000 gallons; then total daily yield = $10,552,000 + 3,100,000 = 13,652,000$ gallons.

This assumes that the ponds or storage basins are full at the beginning of the dry year, and such would be the case if the consumption for the year preceding the dry one were not allowed to exceed the above average of 13,652,000 gal-

lons per day. If, however, the city were using fifteen or sixteen million gallons per day it is very possible the basins might be quite or nearly empty at the beginning of the dry year, and in such case the supply for that year would be reduced to eleven or twelve millions.

The experience of this city in 1871 illustrates this point, and also shows the danger to which a city is exposed when its daily consumption is in excess of the minimum yield of its source of supply.

At the beginning of 1870 the lake was full. The consumption for that year was 15,000,000 gallons daily, and completely exhausted the storage, there being no water in the lake in January, 1871, above the proper flow-line of the conduit.

This latter year was one of partial drought, owing to light summer rains (the total rainfall was 45.39 inches), and an average daily flow through the conduit of 14,300,000 gallons required the use of pumps at the lake to draw water from below its flow-line, the natural yield having been only 13,623,000 gallons daily.

It will be noticed that this yield is almost exactly the yield estimated above for the season of extreme drought, and as the former obtained with a rainfall of 45.39 inches, it might be thought that the latter is an overestimate for a fall of only 30 inches. As just explained, the small supply in 1871 was chiefly due to overtaking the source the previous year, and only partially to a low available rainfall; had the consumption in 1870 been within the estimated least supply, there would have been available for the following year, without pumping, a daily supply of $14\frac{3}{4}$ million gallons.

The estimated least yield of the district now contributing to Lake Cochituate is, then, in round numbers $13\frac{1}{2}$ million gallons daily; but even this quantity will need to be reduced within a brief period, as the town of Natick is now building works to take a supply for domestic use from Dug pond, —

one of the storage basins of the lake district, — and the drainage from that town through Pegan brook, is becoming of a character and an amount that will soon require it to be diverted from the lake.

The question of the sewerage of Natick is discussed in the first report of Mr. Fteley (see Appendix A). He estimates that to secure the purity of the lake water, the drainage from 670 acres of the Cochituate water-shed must be diverted into the Charles river.

As the use of Dug pond by Natick will destroy its value to the city as a storage basin to be drawn upon in a dry season, there are two losses that will in a short time make themselves felt, — first, 670 acres of water-shed; second, 150 million gallons of storage capacity. There is still a third loss, namely, the amount of water consumed by Natick; but this for a number of years will be too small to be taken into account.

The daily supply in a dry year, estimated from the water-shed and storage capacity reduced as above indicated, is 12,800,000 gallons.

The next question to be considered is, What can be done to increase the supply from the lake?

This is treated in detail in Mr. Fteley's report, from which it appears that, first, the lake may be raised two feet, provided legislative authority can be secured; second, a storage basin may be built on Bannister's brook, and its waters turned into the lake; third, a storage basin may be built on Suake brook.

The estimated cost of these extensions is \$274,814, and the estimated increase of daily supply is 2,000,000 gallons.

Interest upon \$274,814, at 6 per cent.	\$16,488.84
Cost of delivering 730,000,000 gallons	16,488.84
“ “ 1,000,000	22.59

That is, the cost of delivering to the conduit each million of the increase of supply would be \$22.59.

There appears to be no engineering difficulty to encounter in raising the lake two feet, but the surrounding towns have hitherto opposed it with sufficient effect to prevent the necessary legislative action, and it is doubtful if such action can ever be obtained.

Bannister's brook now flows into the outlet of the lake below the dam, and thence finds its way into Sudbury river. As its waters have never been diverted, it is presumed that the city now has no right to divert them.

The advantages to be gained by the building of a basin on Snake brook are not of sufficient importance to counterbalance the objections to it. The chief one of these may be mentioned. It will occupy a position directly over the existing conduit, and would render the emptying of the conduit for inspection and repairs hazardous and probably impossible; in fact, it would greatly endanger the safety of this structure even when flowing full, as the head of water over it with a full basin would be twenty-six feet, and the leakage into it would be large, and would take place with such rapid current and force as to carry in great quantities of sand, and thus undermine the foundation and disturb the bricks. Under the present head of only a few feet such action is taking place to an extent that causes much uneasiness, and which, if no remedy is applied, will ultimately destroy this portion of the aqueduct.

If a breach should occur under the basin, the entire destruction of a long section would inevitably result, and the contents of the whole basin might be emptied into some valley farther down on the conduit line.

It would appear, therefore, that in estimating the capacity of the Cochituate district, no account can be taken of an increase of supply from new storage basins within that district. It has, however, been suggested that an increase may be secured by building basins to the east of the lake along the line of the conduit.

This point has been thoroughly studied by Mr. Fteley, and is treated of in his report.

He finds that storage reservoirs of large capacity may be formed in a valley which now discharges its waters into the Charles river, and that a water-shed of nearly eight square miles may thus be made to contribute to the supply of the city. The high-water lines of these reservoirs will be above that of Lake Cochituate; hence they can be used to store the waters of the Cochituate district only under exceptional circumstances; they have, however, a contributing area of their own, which will afford a daily supply of about 5,700,000 gallons of pure water that is not liable to contamination in the future.*

As a new conduit would be needed to render the waters of this district available, it should be treated as a new and independent source of supply, rather than as an addition to the lake district. The new conduit can be easily connected with the old one, and thus be made to aid the latter in conveying the lake water to Chestnut Hill reservoir.

The brook on which the basins would be built empties into the Charles river at a point just below South Natick. It has one or two mills of importance on its banks, and, of course, aids in the supply to the mills below its mouth, on the Charles and Neponset rivers. The mill damages would be relatively large. The estimated cost of works for this source is as follows:—

Cost of storage basins, including land damages	
and short connecting conduit, etc.	\$420,197
Cost of new conduit to Chestnut Hill Reservoir	1,608,000
Total	\$2,028,197

* This quantity added to the yield of the Cochituate district in a dry year would give a total daily yield of about 19½ millions, and if the effect of the improvements in the Cochituate district, that have been suggested, be taken into account, the total daily yield would be about 21½ millions, making no deductions for the sewerage area of Natick.

(No estimate is made of mill damages.)

The cost of delivering each million of gallons to Chestnut Hill reservoir would be :—

Interest upon \$2,028,197, @ 6 per cent.	. \$121,691 82
Cost of delivering 2,080,500,000 gallons	. 121,691 82
Cost of delivering 1,000,000 gallons	. . . 58.49

There is another scheme for utilizing this source, or at least a portion of it, by which a large saving in first cost can be effected, and one of the great objections to the previous scheme removed.*

In the second scheme a new conduit will not be needed, and only the reservoirs on Stevens' brook are to be built; but they are to be made of greater capacity than proposed in the first scheme.

The lake district, with its present storage, will in ordinary years furnish a supply of 15 to 18 million gallons daily, and if a large body of water can be held in store at some other point, to be used in making good the deficiency in a dry season, the average daily supply for each and every year may be made to equal say 17,000,000 gallons, which is all that the existing conduit in its present condition can safely convey.

Reservoirs on this brook can be built which will store 1,600,000,000 gallons, and which, with the natural yield of their water-shed, will furnish a daily supply of nearly 6,000,000. This assumes that they are not ordinarily drawn upon, but are kept full for use in an emergency only, as once emptied it will require two or three years for them to fill again, no water being drawn from them in the mean time. When the dry year comes it is probable that Lake Cochituate

*The Pickerel-pond basin would cover about $\frac{3}{4}$ of a mile of conduit to a depth of 17 feet, and the same objections to its construction would hold as for the Snake-brook basin; objections which must be deemed decisive.

will be found quite or nearly empty at its beginning ; hence, all that can be expected from the lake district will be a little more than the natural flow of the streams, or an average of say 11,000,000 daily.

We have, then, for the daily yield of the two sources in a very dry year, about 17,000,000 gallons ; the estimated increase of supply beyond that to be derived from the lake district in such a year being 3,500,000 gallons.

The lower basin on Stevens' brook is to be connected with the old aqueduct by means of a short line of conduit and a gate-house, and with these structures the estimated cost of the scheme, exclusive of the mill damages on the brook below the lower dam, and on Charles river, Mother brook and the Neponset, is \$210,000.

If a small addition only to the present supply were needed, this scheme would deserve careful attention ; but as matters are, it entirely fails to meet even the immediate wants of the city.

MYSTIC LAKE.

When the storage capacity of any source of supply is small relatively to the extent of water-shed, it will be impossible to hold the produce of the winter's snow and spring rains for use later in the year, and the least yield must be computed from the natural flow of the streams during a short period in the summer and fall of a season of drought, and from the quantity of water held in store at the beginning of that period. The yield thus determined will be the measure of the safe capacity of the source for a domestic supply.

We have the following data for ascertaining the minimum yield of the Mystic district, with its existing capacity for storage.

Water-shed exclusive of water-surfaces 27.5 square miles.

Available storage capacity 380,000,000 gallons.

Experiments upon the Cochituate district have shown that for a period of three months in a very dry season, the nat-

ural daily flow of the streams may be reduced to an average of 130,000 gallons per square mile of water-shed.

During such a period there would be a daily flow into Mystic lake of 3,575,000 gallons, from its drainage area of $27\frac{1}{2}$ square miles. Of course the lake will yield in addition to what it receives the quantity it holds in store. If the lake be full, it will supply 4,220,000 gallons per day for three months, from its storage alone; therefore its average total daily yield for that period will be 7,795,000 gallons.

These figures should be reduced somewhat — to say 7,500,000 — on account of the improbability of the lake being entirely full at the beginning of the period of three months, and to conform to the experience of 1871, when, with a consumption of a little over 5,000,000 gallons daily, the lake was drawn down to a level only 8 feet above the bottom of the conduit.

It is evident from this computation that, within certain limits, the daily yield will rapidly increase with increase of storage capacity, since we have supposed the storage to be drawn upon during three months only of each year.

Mr. Cunningham has made a very careful examination of the valley to ascertain what may be done to increase the storage capacity. The results of his investigations will be found in his report, Appendix B.

He finds that if all the storage facilities above the upper Mystic be utilized, a total daily supply of 17,000,000 gallons may be obtained in the year of drought, and that if the lower Mystic, with its available storage capacity of 281,408,000 gallons and its water-shed of 5.63 square miles, be added, a total daily supply of a little over 20,000,000 gallons may be relied upon.*

In his calculations he has assumed that only 12 inches of rain are collectable in the dry year. As it has been

* This corresponds to a daily supply of from 25 to 30 millions in ordinary years.

ascertained by experiment and observation that this is true for the Cochituate district, and as the rain records show that the rainfall is considerably larger in the Cochituate than in the Mystic valley, it would seem as if this position needed no further support; but as, notwithstanding these facts, there has been considerable discussion about its applicability to the Mystic district, I have had experiments made with apparatus for accurate measurements, to determine as near as may be, from the Charlestown records of 1871, the depth of rain actually collected in that year, and its percentage of the total rainfall. The measurements were made with another object in view also, namely, to establish a formula for computing the yield of the valley from the records of future years.

The method of conducting the experiments and the results derived from them are explained in Mr. Fteley's report, Appendix C. Mr. Thomas Doane, Engineer of the Mystic Board, was associated with Mr. Fteley, and I am informed that they agree in their conclusions.

They find that the amount collected was equivalent to 12.92 inches in depth upon the whole water-shed, which is 43.2 per cent. of the rainfall as measured by the gauge of the Mystic Water works, and $31\frac{8}{10}$ per cent. of the rainfall at the Cambridge observatory. There can be no doubt, after an examination of the records kept at various places, that the results obtained from the Mystic gauge in that year are not applicable to the entire valley. It is not probable that the fall, as an average for the whole valley, was less than 40 inches. The assumption, therefore, that from a rainfall of only 30 inches not more than 12 inches would be collected, seems reasonable and proper.

There are a number of thickly settled and rapidly growing towns in this drainage basin which already have public water supplies, and the sewage of which must soon be diverted from the tributaries of the lake, if it is proposed to maintain

the latter as a source of domestic supply. When this is done, the lake water-shed and the supply from it will be appreciably diminished. Mr. Cunningham's report explains this matter more fully.

After deducting the quantity that it is estimated the population of the territory now supplied from the Mystic valley will use in 1876, but making no deductions for loss by sewage areas, it is found that if that year should prove to be one of drought, there would be a daily surplus of about 7,000,000 gallons, which might be used to supplement the Cochituate supply. This estimate is for the whole basin, including the lower Mystic and Mill brook valley.

The great cost of the large storage basin upon the Abajonna (No. 6), and its position close to, and at a higher elevation than, the Lowell Railroad, will probably prevent its building now or at any future time. The lower part of this basin, if flooded to the depth proposed, will form a very good reservoir; but the upper part will contain some 55 acres flowed less than 5 feet deep.

A reservoir of much smaller capacity may be built at this point, having its flow-line below the level of the Lowell Railroad, which would cost less than half as much as the one proposed.

The tide now flows into and out of the lower Mystic pond, and the water which it contains is salt, varying in degree of saltiness from the surface to the bottom, where it has about half the saltiness of sea-water. The bottom of the deeper portions is covered with a thick layer of mud, from which nauseating gases, such as sulphuretted hydrogen, are constantly escaping in considerable volumes. Whether or not a basin suitable for the storage of potable waters can be formed here is a question which cannot be definitely answered.

That as full information on the subject as it was practicable to obtain within the time allowed for investigation,

might be laid before you, Mr. J. M. Merrick, Analytical Chemist, was requested to make such examinations as he might deem necessary, and to report the results, and give his opinion upon the general question. His report will be found in the Appendix (D).

It has not, however, been handed in at the time of this writing; but I have received from him a letter in answer to certain inquiries, which I quote:—

“In answer to the questions submitted to me by yourself,

“*First.* Whether, before making use of the lower Mystic pond for a storage basin for water for the use of the city, it will be needful to pump out the water now in it;

“*Second.* Whether, a dam having been built and the water pumped out, it will be judicious to use the pond as a storage basin, I have to say, in advance of my detailed report, and at your request, —

“*First.* That analyses given with considerable minuteness and detail in my report answer the first question emphatically in the affirmative, since the water in the lower Mystic is undrinkable, and the contents in saline matters—to be shown in tables—increase with tolerable uniformity to a depth of 80 or 85 feet, until the percentage of salts becomes nearly one-half that of sea-water. In addition to these the water is rendered nauseous by sulphur compounds.

“*Second.* In answer to the question of feasibility of using the natural basin of the lower Mystic as a storage reservoir, I have to say that I think such use can safely be made of the basin after a dam shall have been built and the present water completely pumped out.

“I base my opinion upon the numerous analyses of water and mud-deposits which I have made, and upon my observations and experiments at the pond itself, which lead to the following conclusions, viz. :—

“The source of the present most offensive impurity in the

water of the lower pond, sulphuretted hydrogen, — and perhaps other sulphur compounds, — is derived in part from sewage flowing into the pond, but undoubtedly in much the largest measure from the mutual action of the sulphates in the pond-water contained in the inflowing sea-water, and the vegetable matters at the bottom of the pond.

("No proof has ever been advanced that the sulphurous matters are derived from the soil or rocks at the bottom of the pond.)

"If, then, a dam be built, and the introduction of sewage matter arrested, and the water charged with sulphates and other salts removed, the conditions which render the water impure will be changed. There will still remain at the bottom of the pond a layer of mud charged with saline matters, which will — in contact with the organic substances — continue for some time to decompose, but not being fed by fresh supplies of salt water and sewage will, no doubt, finally become no worse in chemical character than the mud at the bottom of the upper Mystic, or any fresh-water pond. Some considerable amount of free and combined sulphuretted hydrogen was obtained in samples of mud-deposits taken from the bottom of the upper Mystic by myself, September 7, 1874, and such could probably be found in mud taken from any fresh-water pond whose water is, at the same time, unobjectionable for domestic use.

(Signed,)

"J. M. MERRICK."

The sewage matter and vegetable deposits referred to by Mr. Merrick are brought into the pond by Mill brook and the inflowing tide of Mystic river. Mill brook drains a portion of Lexington and the greater part of Arlington.

This last is a thriving town, that is likely to support a large population in the future. It is already supplied with water, and its sewage will soon become a source of serious pollution to the stream. The land of the valley is largely used for

market gardening, and is for that purpose very highly manured; hence, even if the sewage of the town is utilized, instead of being poured directly into the brook, there will be serious contamination from this territory by surface washings in heavy rains. There are various manufacturing establishments on the stream, and gas works near its mouth; it may, therefore, be positively stated that its waters in its lower reach are unfit for domestic use, and should be diverted from the lower pond if the latter is to be used for a storage basin.

The building of a dam will shut out the tide-water flowing through Mystic or Medford river, but for a long series of years, with each inflowing tide, — especially in the fall of the year, — large masses of vegetable matter, such as reeds and grasses from the salt marshes below, have been brought in and become water-soaked, and sunk to the bottom in the still waters of the pond.

The accumulation of organic matter at the bottom of the pond from this cause must be very large; and while, as Mr. Merrick says, it is probable that it will slowly decompose after the introduction of new matter is arrested, yet it is almost certain that a long time will be required to completely destroy it, and thus remove the source of the nauseating gases that render the water unfit for use.

Mr. Merrick points out the necessity of removing the salt water from the basin before it is used for the storage of potable waters. This will be an expensive and not altogether practicable operation. While the pumping is going on, the basin must be kept full, else the surrounding country, which is composed of sand and gravel, will be drained, and the safety of the upper Mystic dam endangered. If fresh water from the upper Mystic is let in as the salt water is pumped out, it might be supposed that the former would remain upon the top, and the latter be gradually pumped from under it. To a certain extent this arrangement of the two waters into upper and lower layers would take place, but there would

be a sufficient mingling of the two to require a much larger volume than the contents of the pond to be removed in order to be rid of the saline matter.

If the water-shed of the pond be rendered ineffective by the diversion of Mill brook, the use of the pond as a storage basin will increase the daily supply by about 800,000 gallons only, and its cost would hardly be balanced by the benefit gained. In any event, it will be so long before its waters can be rendered fit for domestic use, that its effect in increasing the supply should not be taken into account in the present inquiry.

The estimates of cost of this basin given by Mr. Cunningham do not include the cost of diverting Mill brook, nor of pumping out the salt water.

If it be conceded that it is impracticable or not advisable to make use of the lower Mystic, the supply in a season of drought, from the Mystic valley, will be about 17,000,000 gallons daily; and if, further, the capacity of the proposed basin, No. 6, on the Abajonna, be reduced, on account of cost and damage to private property, the daily supply will be about 16,000,000 gallons.

LAKE COCHITUATE AND MYSTIC LAKE COMBINED.

The order of June 15 reads as follows: —

“Ordered, That the Joint Standing Committee on the Water Department ascertain and report whether the present source of our water supply from Lake Cochituate and Mystic lake, combined, can be so utilized as to give an adequate water supply to the city in a season of drought, how great that supply would be, and for how many years that supply would be adequate, and what plan it is necessary to adopt to give us such a supply, and what would be the expense, including the necessary reservoirs, and without them.”

Without additional storage reservoirs the supply from both

sources in such a season would be entirely inadequate for the present wants of the population now depending upon them, as is proven by the experience of 1871, when Lake Cochituate was completely exhausted and the Mystic lake drawn down 3.9 feet below high-water mark,* although the daily consumption from both works in that year was 6,500,000 gallons less than during last year, and some 8,000,000 less than the probable consumption of this year.

The least yield of the Cochituate with its existing storage has been estimated at 13,500,000 gallons daily, that of the Mystic at 7,500,000 ; therefore both sources will yield a total daily supply of 21,000,000 gallons in a season of drought.

The daily consumption from the two sources, in 1873, was 25,600,000 gallons ; hence, had it been a dry year, there would have been a deficiency of supply of 4,600,000 gallons daily.

This is a point of grave importance to the city, and I wish to call attention to the fact that the possible deficiency of supply and its amount, as given above, is not merely a matter of estimate, but is actually proven by the records for 1871. Should the coming year yield no greater supply than did 1871, there would be a daily deficiency of 7 or 8 million gallons.

It has been stated that a large volume of water — 20 or 30 million gallons daily — runs to waste over the Mystic dam for weeks at a time ; that often the waste continues till late in the summer ; or for a period of 5 or 6 months, and the question has been asked why it cannot be made available for supplying Boston during such periods, thus permitting Cochituate lake to fill up with water, for maintaining the supply later in the year when the Mystic may have no surplus.

* In this year there were 230 days in which no water ran to waste over the Mystic dam, of which 172 in the summer and fall were consecutive. There was some waste, however, at the wier of the conduit, estimated to average 1,360,000 gallons per day.

The cost of the machinery for pumping, and of the mains to deliver in Boston proper a supply of 20 or 30 or even 15 million gallons per day from the Mystic, would be very great; and the expense of operating the works, lying idle as they would nearly half the year, and furnishing a constantly varying supply when in use, would be out of proportion to the benefit derived. Moreover, usually when there is an abundance of water in the Mystic there is an abundance also in the Cochituate, and to draw from the former at such times would simply allow waste to take place at the latter, little or nothing being gained at the end of the year.

In the dry year the large waste does not take place, as is shown by the records for 1871, when there were only 135 days in which water ran over the Mystic dam; these were scattered irregularly through the spring and fall months, and the waste varied greatly from week to week.

The storage basins hereinafter proposed will provide for very nearly all the rainfall that enters the streams in a season of drought; and the building of such basins to equalize the daily delivery through the year is the only practicable method of making available the entire yield of such a season.

It is impossible to obtain sufficient storage capacity to prevent a large waste when the snows are melting and the spring rains are falling, in ordinary years. A warm rain falling upon a good depth of snow may cause a flow into Mystic lake of two or three hundred million gallons in twenty-four hours; and at the period when this will happen, the storage basins will usually be full from the accumulations of the previous fall and winter.

It has been shown that the Cochituate supply may be increased about 2,000,000 gallons daily, by making available all the storage room within the lake district and its immediate vicinity; but for various reasons, before given, it is thought the works necessary for this purpose will never be built.

It has been further shown that the supply from this source

may be supplemented by one from Stevens brook, and the two sources be made to yield a daily supply of about 17,000,000 gallons; also that the supply from the Mystic may be increased to about 16,000,000 gallons per day, by building a number of new storage basins above the upper Mystic pond or lake. The lower pond and its water-shed are excluded, for reasons before given.

The combined daily supply from all the sources in a year of drought will be then 33,000,000 gallons, which will afford a surplus of 7,500,000 above the consumption of last year. The daily surplus in an ordinary year would be, as an average, about 13,000,000 gallons, the whole of which would be afforded by the Mystic district; but, even with this fact before us, it is evident that no large expenditure for the special supply of Boston proper from this source would be warranted.

The rapidly increasing demand for water by the population now supplied on the north side of the Charles and Mystic, and the necessary diminution in the yield of the valley that must be caused in the near future by the building of sewers to preserve or restore the purity of the supply, are matters which must be considered, and should have great weight, in forming an opinion on this point.

It is probable that at a moderate cost, and without much diminishing the water-shed, the refuse from existing tanneries and other manufactories may be diverted, or otherwise disposed of; but this form of contamination is increasing, and a still more formidable and dangerous pollution—the sewage from a rapidly increasing population—will soon make itself felt.

It is plain that the purity of this supply can only be maintained in the future at a large cost, and with an appreciable diminution of its quantity. Mr. Cunningham estimates that the drainage from more than three square miles of this territory must be diverted within a few years, which would lessen the supply by nearly 2,000,000 gallons daily.

It may be stated, therefore, that after both the sources have been developed as proposed, a daily surplus of from 6 to 11 millions — depending upon the weather of the year — beyond the present consumption, may be had for use in Boston proper.

The future increase of consumption is a matter of great uncertainty, as it depends upon a number of conditions that cannot be foreseen, such as increase of population, increase of certain manufactures, and of business generally, the weather, the restrictions put upon the use of water, the powers granted to water boards to control the use and prevent waste, etc. The best that can be done is to estimate the increase of the future by that of the past, making such modifications as the circumstances of the case seem to demand.

In making the estimate, I assume that the increase for the next few years will be much less than it has been for the past few, as during the latter period we have had seasons of partial drought and large additions of territory. The yearly increase since 1868 has been nearly ten per cent.

The consumption from both works in 1873 was 25,600,000 gallons daily; let it be assumed that the future increase will be at the rate of seven per cent. yearly; then

for 1874 it will be 27,392,000 gallons daily.

“ 1875	“	29,309,440	“
“ 1876	“	31,361,100	“
“ 1877	“	33,556,377	“
“ 1878	“	35,905,323	“
“ 1879	“	38,418,695	“
“ 1880	“	41,108,003	“

The yield of both sources in a dry year, after the proposed improvements have been made, has been estimated at 33,000,000 gallons daily. From the above table we see that if 1877 should prove to be such a year, the supply would be

fully used. The yield in a season of plenty would be from 40 to 42 million gallons daily, all of which would be required for the estimated consumption of 1880; and the daily yield in an ordinary year would be from 36 to 39 millions, which would provide for the estimated consumption of 1878 or 1879. No deductions have been made in this estimate for the water used by Woburn and Winchester, both of which take a supply from the Mystic water-shed.

SCHEME OF WORKS AND ESTIMATES OF COST.

In devising a scheme of works for the partial supply of Boston proper from the Mystic source, the study has been confined to those of limited capacity and moderate cost, and to such as in whole or in great part may ultimately be made serviceable for the supply of Charlestown, and the other cities now depending upon the Mystic works, their use for the former purpose being regarded as temporary only.

The scheme selected for an estimate is described in the report of Mr. Cunningham.

It is proposed to add a new engine of a capacity of 8,000,000 gallons in twenty-four hours, and the corresponding boilers, to those now in use at the Mystic pumping station, and to lay new force and distributing mains; the latter to pass through Charlestown to the end of Warren bridge, where it will connect with the 20-inch pipe now laid across that bridge. The 20-inch pipe is of less capacity than is desirable, but may be made to serve the purpose required by putting it under the proper pressure at the Charlestown end. The force main will lead to and terminate in a short stand-pipe located on Walnut Hill, near the Charlestown reservoir.

The object of the stand-pipe is to allow the head of water under which the distribution is made to regulate itself to suit the hourly varying pressure of the Cochituate supply in Boston.

As has been explained in a previous report, it is not thought advisable to isolate a portion of the distributing system of pipes in the city for the exclusive use of a small supply, but rather to so regulate the pressures, that the water from both the Cochituate and Mystic works may flow through the same pipes, and thus provide for an adequate supply in case of a large fire.

If the water be drawn from reservoirs of different elevations (the elevation of Chestnut Hill reservoir is 124, and of the Charlestown reservoir 147 feet), this end can be well attained only by a frequent operation of stop-gates, requiring the constant attention of a man, since the Cochituate pressure at the North End, where the supply would be received, varies during the day from 38 to 48 lbs. ; if, however, the supply be taken from a stand-pipe, the level of water in it, or the head, will, if required, adapt itself to a uniform flow in the pipes.

The works proposed can deliver from five to seven million gallons daily, by varying the head in the stand-pipe ; the estimate of their cost is \$393,490, based upon the use of cast-iron pipes for force and delivery mains.

The total cost of the proposed improvements and additions to the Cochituate and Mystic works is as follows :—

Cost of reservoirs, etc., on Stevens' brook	. \$210,000 00
“ “ “ in Mystic valley	. 738,542 00
“ engine, force and delivery mains, stand-pipe, etc.	 393,490 00
Total	 <u>\$1,342,032 00</u>

In the preceding estimate, no account is taken of mill damages on Stevens' brook, Charles and Neponset rivers. These, of course, would be small, as the mills will be deprived of the flow from only four and a half square miles of watershed. The right to make this diversion must be secured by act of the Legislature.

No estimate is given of the cost of sewerage either in the Cochituate or Mystic valley, as this must be constructed whether the proposed improvements are made or not.

In concluding this portion of the report, I desire to say that even if it should be decided not to bring the Mystic water to this side of the Charles river, no time should be lost in providing more storage, for the use of Charlestown. This matter will undoubtedly soon be brought to the attention of the City Council, by the Mystic Water Board, and no extended remarks are needed here.

Also, that in an emergency within the next year, during those months that water is wasting over the dam, a supply for Boston proper of, say four or five million gallons daily, may be obtained from the Mystic works without any addition to the pumping machinery, and none to the delivery mains other than is now being made. This cannot be done, however, without some inconvenience to the consumers on the high grounds in Charlestown.

CHARLES RIVER.

The order of the City Council of June 29th reads as follows:—

"Ordered, That the Joint Standing Committee on water be requested to examine the Charles river, and report in print upon its availability as a source of supply to the city of Boston, giving the estimated cost of the works required to bring its waters to Chestnut-hill reservoir."

In a report, made in 1845 by Commissioners John B. Jervis and Walter R. Johnson, is printed a table showing the summer flow of the Charles river at Newton Upper Falls, the figures for which were obtained by gaugings made during a period of eight weeks in August, September and October of that year.

The Commissioners say :—

"It will doubtless be remarked that considerable diversities existed in the flow of the river on consecutive days; this was no doubt owing, in some measure, to the different rates at which the water was used at the mills higher up on the river, as at Dover, Natick, and elsewhere. The exceeding sluggishness of the stream prevents these differences in the rate of discharge above from being felt immediately, or, indeed, until after some days have elapsed. On Sundays, the river is a long series of pools without motion, except that of the portion of water which happens to be *in transitu* from an upper to a lower pool."

"Several rains fell during the time of our gauging, and temporarily raised the river. The effect of these is sufficiently observable."

"Daily Flow of Water in Charles River, as Gauged above the Upper Falls, Newton, from August 21st to October 14th, 1845.

AUGUST.

DATE.	No. of sets of Observations.	TIME OF COMMENCING AND TERMINATING OBSERVATIONS.		Total No. of gallons disc'd each day.
		Beginning at.	Ending at.	
21	4	6.25 A.M.	7.00 P.M.	20,298,752
22	5	5.25	7.00	22,574,052
23	5	5.25	7.00	25,271,860
24	5	5.25	7.00	42,897,150
25	5	5.25	7.00	69,485,166
26	5	5.25	7.00	40,334,888
27	5	5.25	7.00	34,377,284
28	5	5.25	7.00	39,008,690
29	5	5.25	7.00	38,863,930
30	5	5.25	7.00	33,263,832
31	5	5.25	7.00	22,689,390

"Daily Flow of Water in Charles River, etc.

SEPTEMBER.

DATE.	No. of sets of Observations.	TIME OF COMMENCING AND TERMINATING OBSERVATIONS.		Total No. of gallons disc'd each day.
		Beginning at.	Ending at.	
1	5	5.25 A.M.	7.00 P.M.	20,211,754
2	5	5.25	7.00	23,817,872
3	5	5.25	7.00	22,482,704
4	5	5.25	7.00	22,616,180
5	5	5.35	7.00	24,101,222
6	5	5.25	7.00	23,140,362
7	4	5.25	4.00	20,370,142
8	...	.....	.....	.....
9	...	.....	.....	.....
10	2	4.30 P.M.	6.30	14,045,900
11	5	5.30 A.M.	6.30	16,790,360
12	5	5.20	6.25	18,972,980
13	5	5.15	6.25	19,653,040
14	4	6.00	6.30	16,969,652
15	5	5.20	6.05	9,367,100
16	5	5.30	6.10	10,069,090
17	5	5.40	6.10	17,752,916
18	5	5.40	5.50	20,355,930
19	5	5.45	5.50	18,566,920
20	5	5.40	5.55	20,586,064
21	2	6.10	9.10 A.M.	21,506,770
22	5	5.35	5.55 P.M.	12,116,889
23	5	5.45	5.55	19,617,538
24	5	5.45	6.00	22,096,016
25	5	5.40	5.50	21,741,854
26	5	5.55	5.50	23,334,182
27	5	5.50	5.45	22,226,012
28	...	.....	.....	Sunday.
29	5	5.45	6.15	13,913,892
30	5	5.30	6.10	19,099,878

"Daily Flow of Water in Charles River, etc.

OCTOBER.

DATE.	No. of sets of Observations.	TIME OF COMMENCING AND TERMINATING OBSERVATIONS.		Total No. of gallons dis'cd each day.
		Beginning at.	Ending at.	
1	5	5.50 A.M.	6.00 P.M.	23,262,558
2	5	5.40	6.00	22,398,120
3	5	5.40	6.00	22,550,180
4	5	5.50	5.50	24,043,614
5	...	.....	.....	Sunday.
6	5	5.55	5.50	30,033,566
7	5	5.50	5.55	39,895,524
8	5	5.45	5.50	39,838,792
9	5	6.00	5.45	39,576,906
10	5	6.13	5.35	48,977,908
11	5	6.20	5.40	46,607,046
12	...	.....	.....	Sunday.
13	5	5.50	5.45	43,169,840
14	1	5.50	5.54 A.M.	45,845,780

"We have seen published statements of various estimates as to what this river would furnish per day. Some have placed it as high as 30,000,000 gallons. It will be seen by the actual gauging on the 15th and 16th of September, that it did not, on the average of the two days, then discharge one-third of this quantity; and that, for the whole month of September, its average daily flow was 19,108,451 gallons; or less than two-thirds of the published estimate. The lowest gauging stated by Mr. Crehore (cited by Mr. Wilkins in his 'Further Remarks,' etc.) viz., that of July 26th, 1841, was $31\frac{2}{7}$ cubic feet per second, equal to 20,366,640 gallons per day."

"When reduced to its lowest stage during our gauging, Charles river supplied 9,367,100 gallons. By the statement of Mr. Hurd, one of the proprietors of the paper-mills at

Newton Lower Falls, we learn that in the latter part of October, after our observations terminated, the water was as low as it had been at any time in September; and that in August, it had, at its lowest stage, been as low as in either of the other two months. Of this testimony we have no reason to doubt the correctness, as Mr. Hurd has daily occasion to observe the rate of supply to his manufactory."

"That the present, has not, thus far, been a year of extraordinary drought, is proved by the rain gauges of the Cambridge observatory, kindly furnished to us by Mr. Bond, and that of Dr. Hale, kept at his residence in Boston."

The average daily flow for the 50 days of gauging was 26½ million gallons; the average during the month of September was 19,000,000. To obtain the entire flow of the river during the above periods, these figures should be increased by 33 per cent., as one-third of the flow is diverted into the Neponset river through Mother brook, at a point above where the gaugings were made; but it will be observed that even with this increase the natural flow is too small to furnish an adequate supply to this city. Storage basins will be needed therefore, to provide the requisite quantity as well as to assure the desirable purity.

By what project the waters of this river should be made available for a domestic supply is a question which requires for its solution much more time and closer study than it has been possible thus far to give it. Even the best point for taking the water is — looking well to the future and weighing the cost of works — a matter of some doubt, and there are many schemes of works to choose from, each of which has its merits. Several of these schemes are noticed in the report of Mr. Fteley (Appendix E) and he has selected for estimates of cost and description a number which are representative, and which offer sufficient data for forming an opinion of the value of the river as a source of supply, and for comparing it with the other sources that have been before reported upon.

The water may be taken at Newton Lower Falls, at either of two points in Newton Upper Falls, at West Roxbury, at the village of Greendale in Needham, and at a point just above South Natick. For most of these places two or more schemes of works differing in important details might be proposed.

The study that has just been made has developed some new facts, and changed some preconceived opinions. For instance, it was thought that the topography of the country below Natick and the situation of the towns along the river, were such as to render impossible, or not practicable, the building of capacious storage basins with a sufficient depth of flow. The recent surveys show, on the contrary, that a very large one may be built in that territory, by the erection of a dam at Newton Upper Falls. Its water surface would cover about 2,900 acres, and its available capacity would be 7,500,000,000 gallons. The depth of flowage would not be so great as is desirable, but it is thought it would be sufficient to prevent the growth of plants on the bottom, except when drawn down lower than ordinary use will require. It will be a costly basin to build, and will destroy some 20 or 30 dwellings, but there are no engineering difficulties of importance to overcome in its construction; the main objections to it are sanitary. It is possible that with its relatively high level and proximity to Dedham — at its very doors as it were — it might affect prejudicially the health of that town; and it is liable to receive in the future, the sewage from a large population in the valley above. When Boston shall have a population that will require a daily supply of 50,000,000 gallons of water, the valley of the Charles, for some miles up, will be thickly settled, and the river must be the means of conveying its sewage to the sea.

This basin will cost about the same as one of larger capacity that may be built above South Natick (described in

Appendix E), and in case the supply is taken at any point above Dedham, can serve no purpose, except it be to store water for the use of the mills.

The whole valley of the Charles has been very thoroughly examined by the Commission appointed to report upon the purity of the waters from various sources, and it is probable that the question, above mentioned, of the danger (or otherwise) of sewage contamination to the supply if taken at any point below South Natick, will be fully treated in its report; not knowing, however, the opinions that will be formed on this point, Mr. Fteley has described and made estimates for a number of schemes of works, some of which are based upon taking the supply below Dedham, and one of which provides for the filtration of the water.

The following are the schemes of works for which estimates of cost have been made. In each of them the water is taken from the river at an elevation which necessitates pumping, and as a basis for calculating its cost a daily supply of 50,000,000 gallons is assumed.

Scheme No. 1.

Water taken near Newton Lower Falls:—

Cost of works, including a large storage basin
to be built either at Dedham or above

South Natick \$3,554,000 00

Cost of delivering each million of gallons 17 05

Water stored but not filtered.

Scheme No. 2.

Water taken at Newton Upper Falls:—

Cost of works, including a large storage basin

at Dedham \$3,575,000 00

Cost of delivering each million of gallons 16 07

Water not filtered but taken directly from the
storage basin.

Scheme No. 3.

Water taken at Newton Upper Falls. Storage basin at Dedham or above South Natick and filter beds at Newton Highlands : —

Cost of works	\$5,366,239 00
Cost of delivering each million of gallons	25 30

Water stored and filtered.

The estimate does not include the cost of roofing over the filter beds. The ice and snow of our severe winters, and also the heat of our summers, may make such protection necessary.

Scheme No. 4.

Water taken near Greendale, in Needham. Two storage basins ; — a large one above South Natick, and a small one at the point of taking : —

Cost of works, about	\$4,500,000 00
Cost of delivering each million of gallons, about	20 00

This scheme will cost just about the same as scheme No. 5, and, having the objection of a greater liability to pollution of the water by sewage, has not received much attention.

Scheme No. 5.

Water taken at a point about one mile above the village of South Natick, where it is proposed to build a dam and form a large reservoir of an available capacity of about 9,000,000,000 gallons : —

Cost of works	\$4,906,667 00
Cost of delivering each million gallons .	19 96

Water not filtered, but taken directly from storage basin.

This basin would cover an area of nearly 4,000 acres to an average depth of about 9 feet, which depth is less than is

desirable. Three hundred and fifty-four acres would be covered with less than five feet of water even when the basin is full. It is rarely, however, that artificial basins can be formed by simply building a dam across a valley, without causing considerable shallow flowage. Lake Cochituate, with a total water area of about 800 acres, has nearly 200 acres flowed not more than five or six feet deep.

As has been stated in a previous report, no reason is known why the waters of Charles river, if taken above South Natick, should not prove of satisfactory quality.

The preceding estimates do not include the cost of mill damages. The mills that will be damaged are situated on the Charles river at and below South Natick, on Mother brook, and on the Neponset river below the mouth of Mother brook. Tables giving their location, character of manufactures, height of dams, number of wheels, etc., will be found in the report of your sub-committee, City Doc. No. 38, pages xviii.-xxi. If all the water of the river is to be paid for, the mills upon the Charles and upon Mother brook will receive nearly the value of their entire power, and there appears to be a marked difference in this respect between the damages the city will incur in taking the Sudbury and those to be incurred in taking the Charles. The Sudbury is a branch of a larger river (the Concord), upon which nearly all the mills affected are situated, and in diverting the waters of the former the mills upon the Concord are deprived of only about one-fifth of their power. (The mills at Saxonville are the only ones located on the Sudbury itself, below the point of taking.) The Charles, on the contrary, is a main stream, and when its waters are diverted the mills below lose nearly the whole of their power.

To compare the Charles-river schemes with that of the Sudbury, some changes must be made in the estimates of cost.

Since the date of the Sudbury-river report, Jan. 27, 1873,

the consumption in the city has largely increased, and in consequence it will be impossible to draw Chestnut-hill reservoir down, — as was then proposed, — to facilitate the building of the various inlet chambers, and to make the connection with the distributing mains. This has necessitated an entire change of the plans for that part of the work which, in connection with other modifications, has increased the cost about \$200,000.

The Sudbury-river estimate — as stated — included the cost of building the three lower basins only, as the others would not be needed for some years to come. The cost of the upper basins will be about \$350,000; hence the estimate for the complete scheme will be \$5,338,318.

The estimate of Charles-river scheme No. 5, is \$4,906,677. To this should be added a sum the interest of which will equal the yearly cost of pumping. This sum, reckoned upon the basis of a daily supply of 40,000,000 gallons, would be about \$1,000,000; hence for purposes of comparison the Charles-river estimate should be stated at 5,900,000.

The Charles will furnish much the larger volume of water. By increasing the storage capacity above that now proposed, a supply of 80,000,000 gallons daily may be obtained from it.

The Sudbury will furnish its waters by gravitation, and the storage basins that may be built upon it would have a much greater average depth than those proposed for the Charles.

(See Appendix of City Doc. No. 29, 1873.)

So far as quality of water is concerned, there is very little difference between the two sources, if the comparison be confined to that portion of the Charles which is above South Natick.

The data needed to determine at what point it is best to take the water from this river will be found in the report of the Commission, before referred to. If it be found admissible to take it without filtering from the Dedham basin at Newton

Upper Falls, and satisfactory legislation for this purpose can be obtained, then scheme No. 2 is the one to be used for comparison with other sources. The cost of works in that scheme is \$3,575,000. The yearly cost of pumping 40,000,000 gallons per day, capitalized at 6 per cent., is \$1,200,000, which, added to the cost of works, gives a total of \$4,775,000.

Respectfully submitted,

JOS. P. DAVIS.

APPENDIX A.

REPORT

OF

MR. A. FTELEY,

ON

INCREASING THE SUPPLY FROM

LAKE COCHITUATE.

APPENDIX A.

OFFICE OF BOSTON WATER WORKS, ADDITIONAL SUPPLY,
So. FRAMINGHAM, Sept. 1, 1874.

J. P. DAVIS, *City Engineer*: —

DEAR SIR: The following is the result of the examination of the water-shed of Lake Cochituate, made in accordance with the instructions received in July last, to ascertain whether the supply of water from that source can be increased, by what means, and to what extent.

At the time of the construction of the Cochituate water-works, the high-water mark of the lake was established 132.36 feet above mean high tide. As soon as it was found necessary to increase the water-supply of Boston, the high-water mark of the lake was raised two feet (in 1859); and, two years afterwards, Dudley pond, with a water-shed of over 500 acres, was connected with Lake Cochituate.

These two additions were secured at a comparatively small cost, and it was then supposed that the effective capacity of the lake had reached its extreme limits.

The territory adjacent to the lake has been examined, however, with a view of obtaining either an increase of its drainage area, or additional storage. Both can be secured; whether in a satisfactory manner the following will show.

Of the tributaries of Lake Cochituate, a few only are susceptible of improvement; Shakum pond cannot be raised; the cost of a dam in the extensive and low meadows and swamps which surround it, would not be justified by the doubtful advantage to be derived from storing the water collected in a limited district; no opportunity for storing water can be found, either on Beaver dam or Course brooks, on

account of the slight fall of their channels from their sources to the lake.

The only possible ways to increase the storage or watershed are :—

1st. To raise the high-water mark of the lake once more.

2d. To construct a dam and form a reservoir in the watershed of Snake brook.

3d. To turn into the lake the drainage of the watershed of Bannister's brook, and to form there another storage reservoir.

RAISING LAKE COCHITUATE.

It has been already stated that the storage capacity of the lake is, at present, large enough in proportion to its drainage area. To add to it is to increase the chances of having a large portion of the bottom of the southern meadows left exposed, which, in the vicinity of as large a town as Natick, may be found objectionable. As early as 1854 — consequently before the first raising of the lake — it appears, from the reports of the City Engineer, that there had already been complaints from this cause.

Moreover, it might be a difficult matter to secure the necessary legislation for raising the level. When it was raised two feet in 1859, it seems that the neighboring towns objected, and the Water Board, which had been through the necessary negotiations to attain that end, wrote the following in its Annual Report for 1861 :—

"By the Act of the Legislature of this Commonwealth, of 1860 (ch. 184), the city was authorized to raise the dam at the outlet of Lake Cochituate, to the height of ten feet above the floor of Knight's flume (so called). In accordance with this act the dam was raised, and, in the judgment of the Board, we have now reached the greatest capacity of Lake Cochituate for the supply of water. In case the supply is insufficient, recourse should be had to other sources, which may or may not be connected with this lake.

"To raise the lake any higher will require legislative action, and would be attended with such expense, and with difficulties so great and so numerous, that the Board are decidedly of the opinion that it will be a mistaken policy to attempt it."

In the face of such a statement, of men who had investigated the question more thoroughly than it is possible to do now, without going once more through the same negotiations, it is imprudent to assert that the lake can be raised higher than it is at present.

The engineering problem, however, can undoubtedly be solved if proper legislation can be secured, and all objections removed, as there is no serious difficulty to be encountered in raising the level two feet more. The high-water mark would then be 136.36 feet above mean high tide.

The work to be done in connection with this scheme is as follows:—

The dam at the outlet of the lake must be raised, and the gate-house altered.

The protection of the banks in the upper division must be extended, one culvert rebuilt, and the three roads that cross the lake, raised. Considerable labor must also be spent along the banks to protect property and generally meet the requirements of the case.

The flowage of the lake would extend in Snake-brook valley beyond North Main street. Along Beaver-dam brook it would extend north of the railroad and along Course brook as far as its crossing with Speen street, some distance from the lake.

It is estimated that the cost of raising the level two feet, including land damages, would amount to \$43,300.

The water area would cover 849 acres, instead of 801, as at present.

The increase in the storage capacity					
would be	.	.	.	.	537,617,500 gallons.
Present capacity	.	.	.	.	2,011,165,000 “
Total capacity after raising	.	.	.	.	2,548,782,500 “

RESERVOIR IN SNAKE-BROOK VALLEY.

A storage reservoir, receiving the drainage of about 1,200 acres of the water-shed of Lake Cochituate, can be formed in the lower portion of the valley of Snake brook, by erecting a dam at a short distance east of North Main street. No other opportunity for storing the water can be found farther up the valley, on account of the rapid descent of the brook.

The ground to be covered by the reservoir is good, and well adapted for such a structure; the flowage is satisfactory, the land to be flooded being generally open, and the wet meadows of comparatively small extent.

The water area of the reservoir covers 78 acres, and its extreme depth near the dam measures $19\frac{1}{2}$ feet. The high-water mark is established 153 feet above mean high tide.

The principal objection to the construction of this reservoir is that it covers nearly 2,000 feet of the Cochituate aqueduct, which would consequently be submerged under 26 feet of water. It is obvious that the conduit would then be in a very dangerous position.

The cost of the Snake-brook reservoir, including dam and land damages, is \$79,655.

Its available capacity is 175,792,900 gallons.

BANNISTER'S BROOK DIVERTED INTO LAKE COCHITUATE, AND A STORAGE RESERVOIR TO BE CONSTRUCTED IN ITS WATER-SHED.

Bannister's brook runs in a northerly direction, almost parallel with the northern division of Lake Cochituate, through a small valley, the lower part of which is below the level of the lake, the water being only 129 feet above mean

high tide, at the point where it crosses the Worcester turnpike. This brook empties into the outlet of the lake, and consequently its water-shed is not utilized.

The meadows situated between Bannister's brook and the lake being only 130 feet above high tide, it was not found advisable, at the time of the construction of the water works, to cover them with only two feet of water. They were artificially drained into Bannister's brook, and a dam was erected on the margin of the lake, almost opposite the keeper's house. At present, these meadows are about four feet below the high-water mark of the lake.

The water-shed of Bannister's brook could be made to drain into the lake, at a small expense, by erecting a shallow dam on the brook, about 300 feet south of its crossing with the Worcester turnpike; but there would be, when the level of the lake is lowered, a large area of shallow and objectionable flowage.

The above scheme having been rejected originally, not without reason, the possibility of combining it with the erection of a storage reservoir has been examined into. The water-shed of Bannister's brook would thus be saved for the lake, and the storage capacity of the reservoir would be more than sufficient to equalize the flow of the brook.

To secure that result, a dam, 20 feet high at its centre, and 600 feet long, must be erected across the brook, near the road from Natick to Saxonville; another dam, 1,600 feet long, and of various heights, must be built on the location of the present one, along the western bank of the lake, and it is to be provided with an overflow, and suitable sluice-gates. The Saxonville road, and the road from Framingham to Cochituate, being considerably below the proposed level of the reservoir, a large amount of labor and material must be spent to bring them up to the proper grade.

The high-water mark has been established 141 feet above mean high tide, on account of the Saxonville branch railroad, and

also on account of the extensive grading to be done to bring the roads to the required elevation.

The water in this reservoir is not supposed to be drawn lower than the actual high-water mark of the lake. Its available storage capacity is equal to 299,370,000 gallons.

The total drainage area of Bannister's brook, above the proposed dam, is 1.13 sq. miles.

Equal to	723 acres.
Water area	181 "
Available water-shed	<u>542 "</u>

It may be observed that the capacity of the reservoir is large when compared with the extent of the water-shed; and, if it was emptied in a dry year, it would require the whole rainfall of an average year to fill it again.

The cost of Bannister's-brook reservoir, including land damages, is \$151,859.

From the above it appears that the cost of raising the lake, and of erecting reservoirs in Snake brook and Bannister's brook valley would be \$274,814.

Below will be found what supply can be expected from such an expenditure.

The water-shed of Lake Cochituate, including	
that of Dug pond, covers	12,077 acres.
The area of the water-shed of Dudley pond is	<u>544 "</u>
Total	12,621 "
Deducting the amount of water surfaces reduced in a dry year, to	<u>800 "</u>
The available water-shed is at present	11,821 "
Equal to 18.47 sq. miles.	

The available water-shed, if the reservoirs above described

were constructed, and the lake raised, would be different.

The water-shed of Bannister's brook must be added, and the water area of Snake-brook reservoir deducted. It has been found advisable, also, in the following calculations, to deduct from the water-shed of the lake the area which would be withdrawn from it by the diverting of the sewage of Natick into some other water-shed. Natick is constructing its water works, and, before long, the want of a system of sewerage will be felt. Moreover, the amount of sewage matter which is conveyed into the lake by Pegan's brook and the eastern tributary of Dug pond is, and has been for a long time, for good reasons, a source of anxiety for the Water Board, who, as early as 1864, had some surveys made to ascertain whether Pegan's brook could be diverted, and at what cost. The question has been considered again, and the area which would be withdrawn from the water-shed of the lake, by the construction of a system of sewerage, has been found to be equal to 670 acres. A description and an estimate of the cost of a sewer to divert into Charles river the sewage of Natick will be found at the end of this report.

Present area of the available water-shed of

Lake Cochituate, as above . . .	11,820 acres.
Add water-shed of Bannister's brook . .	542 "
	12,362 "

Deduct area drained by the pro-

posed Natick sewer . . . 670 acres.

Water area of Snake-brook reser-

voir 78 "

748 "

Area of available water-shed of Lake Cochit-

uate as it would be 11,614 "

Equal to 18.15 sq. miles.

The storage capacity would be as follows, viz. : —

Lake with surface raised	2,548,782,500 gallons.
Bannister's-brook reservoir	299,370,000 "
Snake brook "	175,793,000 "
Dug pond	150,000,000 "
Dudley pond	250,000,000 "
	3,423,945,500 "

Assuming that in the year of drought 12 inches of rain can always be collected, the total yield of 11,614 acres would be 3,784,445,128 gallons, corresponding to a daily average of 10,368,300 gallons.

A storage capacity of 120 times that amount, viz., 1,244,196,000, has been found by previous experience to be sufficient to equalize the daily flow, leaving a surplus storage of 2,179,749,500 galls.

From this quantity must

be deducted 400,000,-
000 galls., because the
storage of the lake has
always been computed
from a point 3' 4" above
the bottom of the con-
duit, at which height the
flow through the aque-
duct is too small 400,000,000 galls.

Deduct also the storage

of Dug pond, which
will be utilized by the
town of Natick . 150,000,000 galls.

550,000,000 galls.

Surplus storage 1,629,749,500 "

Corresponding to a daily average of . 4,465,000 "

The amount furnished by 12 inches of rain
on the water-shed was found to be . 10,368,300 "

Total daily average . . . 14,833,300 "

A somewhat smaller result is obtained by basing the computation of the average daily yield upon the fact that for a series of eight years the average yearly rainfall collected has been equal to 16 inches, and 14,500,000 gallons has been adopted as the average daily yield that could be obtained in a year of drought from the water-shed of the lake; *i. e.*, about 2,000,000 gallons more than it could furnish at present.

Thus, an extra supply of 2,000,000 gallons can be secured in a year of drought at an aggregate expenditure of \$274,814; but it must be remembered that of the three schemes described, one, the Snake-brook reservoir, ought not to be executed on account of its endangering the aqueduct for a considerable portion of its length; another, the Bannister's brook reservoir, is thought to be too expensive when compared with the benefits to be derived from it; the third, the raising of the lake, if we are to believe the testimony of a former Water Board, cannot be done without meeting great difficulties.

ADDITIONAL WATER SUPPLY FROM NONESUCH POND, STEVENS' BROOK, PICKEREL POND AND MORSE'S POND.

As early as 1854, the constantly increasing consumption of water in Boston had induced the Water Board to consider the expediency of finding an additional source of supply, and it had been then suggested by the City Engineer that water might be stored in Nonesuch pond to increase the flow in the aqueduct in case of need. The same source of supply has been mentioned again recently.

It has consequently been thought proper, in connection with the examination made of the water-shed of the lake, to consider whether any source of supply to be found on the line of the aqueduct could be so improved as to furnish to the city an additional amount of water.

The principal source of supply, and, it is believed, the

only one on the line of the aqueduct that can be improved, is to be found in the water-shed of Nonesuch pond, Stevens' brook, Pickerel pond, and Morse's pond.

Nonesuch pond, situated partly in Natick, partly in Weston, drains a tract of country in area . 2.94 sq. miles.

The drainage grounds of Pickerel, Mud and

Jennings' ponds cover an area of . . . 1.81 “

The rest of the water-shed of Morse's pond, including its water surface, has an area of 2.98 “

Total area of the water-shed of Morse's pond 7.73 “

The waters of Morse's pond flow through Waban lake and creek into Charles river; if they were to be diverted, some legislation would be required to secure the necessary rights.

The district is but little inhabited and contains much woodland; the lower part of the valley of Pickerel pond is occupied by a swamp which extends on both sides of the Worcester turnpike.

There are great facilities for storing water; a large proportion of the valley of Nonesuch pond can be made an extensive reservoir; almost the whole of the valley of Pickerel pond can be improved in the same manner; the surface of Morse's pond can also be raised 20 feet. The last two reservoirs, however, would be objectionable in one respect, as the conduit would be submerged under their waters, 16 feet in Pickerel pond reservoir, and 8 feet in Morse's pond.

These ponds are so grouped that they could be drawn independently into the conduit, or be in communication, if necessary; but the whole capacity of Morse's pond could not be utilized, on account of its present level being $5\frac{1}{2}$ feet below the bottom of the conduit at Dedman's-brook waste-weir.

These reservoirs, which might be very desirable, if in connection with a large water-shed, would have the following capacities : —

Nonesuch pond raised	.	.	.	1,692,000,000	gallons.
Pickerel pond	“	.	.	1,251,000,000	“
Morse's pond	“	.	.	1,000,000,000	“
Total	.	.	.	3,943,000,000	“

The corresponding water area would be 847 acres, leaving 4,273 acres of available water-shed.

The capacity of these reservoirs (principally of Nonesuch-pond and Pickerel-pond reservoirs) is too large when compared with the area of their water-sheds; it would be difficult to fill them. It is an error to believe that an indefinite increase of the storage capacity can be beneficial; the amount of water kept in store must be proportionate with the average amount of rainfall that can be collected on the drainage grounds.

It has been found, by comparison with the records of the yield of Lake Cochituate for the last twenty years that, in building basins of an available capacity of 1,500,000,000 gallons in this water-shed, a supply of 18 inches of rain can be secured regularly for a similar series of years, the time necessary to fill the reservoirs again after emptying them varying between one and six years.

A storage capacity of 1,500,000,000 gallons has consequently been adopted as meeting the requirements of the case.

To secure this amount of storage room, Nonesuch pond proper will be raised 10 feet and a reservoir will be erected above it. The surface of Pickerel pond will also be raised to grade 143 above mean high tide. The water-shed of the latter being very small, the drainage area of Stevens' brook, from Nonesuch pond to Morse's pond, will be connected

with it by a small reservoir constructed on Stevens' brook and a conduit which will be put in direct communication with the Cochituate aqueduct by proper sluices.

The water from these various sources will be gathered into Morse's pond, which will be raised 12 feet to bring its level to the same height as the top of the Cochituate aqueduct.

In this manner Morse's pond will be utilized as a settling basin, and as a channel to convey the water into the aqueduct, and its storage will not be utilized; it has been deemed proper to adopt that plan rather than to raise the level of the pond above the conduit.

ESTIMATE OF COST.

Nonesuch pond is to be raised 10 feet; its actual elevation above mean high tide is 165.73 feet. It is shallow and surrounded by generally steep hills. The raising being limited to 10 feet, the flowage is good; no road is flooded, no house touched.

Its cost, including land damages, is, \$60,720.

Its available capacity, 180,000,000 gallons.

Its water area, 112.97 acres.

The reservoir above Nonesuch pond is formed by the erection of a dam 20 feet high at the inlet of the pond; two small dykes are also required:

This district is covered with woods, but would give a good flowage.

The cost, including land damages, is \$69,245.

The available capacity 450,000,000 gallons.

The water area, 195 acres.

Pickerel pond is situated in a wide and swampy valley crossed by the Worcester turnpike and surrounded by steep hills.

The flow line is established 143 feet above mean high tide, *i. e.*, 10 feet below that of Snake-brook basin; the average depth is 13 feet.

In this case, the Cochituate aqueduct would be 16 feet under water for a considerable distance, and the Worcester turnpike raised for nearly 3,000 feet.

The land is not valuable, a great portion being swampy and covered with brush; two dykes, one at Oak street, the other north of Pine street, must also be erected across the trench in which the aqueduct is constructed.

Cost, including land damages, \$131,332.

Available capacity, 850,000,000 gallons.

Water area, 281.6 acres.

It might be said that instead of erecting three reservoirs, viz., one at Nonesuch pond, one above it, one at Pickerel pond, at a cost of \$261,297, it would have been preferable to omit the last reservoir, which is objectionable in some respects, and to raise Nonesuch pond to the level of the reservoir located above it, thus creating, at a somewhat smaller cost, a large basin of 400 acres, containing nearly 1,700,000,000 gallons.

But Pickerel pond is necessary, to catch, through Stevens' brook, the drainage of nearly two square miles of water-shed, which, otherwise, could not be stored, thus reducing considerably the amount of water to be obtained from the source.

Morse's pond has been included in the scheme, because, if it was excluded, more than a square mile of water-shed would be lost. A rise of 12 feet will bring the flow-line to the height of the top of the aqueduct. This reservoir will be kept full, and, as it receives the drainage of all the others, it will be directly connected with the conduit.

The cost, including land damages, of improving Morse's pond and raising the Worcester turnpike, is \$74,900.

Cost of regulating reservoirs on Stevens' brook	\$27,000
“ of conduit between Stevens' brook and Pickerel pond	} \$57,000
“ of connecting chamber on Cochituate aqueduct	
“ of gate-house on Morse's pond	

It has been said before that, with the proposed storage, 18 inches of rainfall could have been secured on the water-shed for a series of 20 years.

That amount of rainfall, on an available water-shed of 4,336 acres, gives 2,119,337,000 gallons, corresponding to a daily supply of 5,806,400 gallons per day.

If the average daily yield is calculated on the basis of a series of eight years, with an average collectible rainfall of 16 inches, it is found that the storage is larger than necessary to equalize the flow, and that, in increasing the average daily yield by the quantity to be derived from that surplus storage, the daily supply is equal to 5,650,000 gallons.

5,700,000 gallons per day has been adopted as being the average daily supply to be obtained in a dry year from the water-shed.

This quantity, added to the average daily supply to be obtained from Lake Cochituate, viz., 14,500,000 gallons, gives a total supply of 20,200,000 gallons, that can be obtained from both sources combined.

This amount of water cannot be conveyed to Chestnut-hill reservoir through the Cochituate aqueduct; an additional one must be provided for that purpose, and it must be made large enough to convey, together with the former, the amount of water supplied in an average year, or a large part of it, and to be used alone temporarily in case of accident and repairs to the other. It is desirable, also, to build a conduit large enough to admit men for the purpose of examination and repairs.

Consequently, the required conduit has been supposed to be of the same size as the Cochituate aqueduct.

Although no actual survey has been made for a new line, it seems that there is no other resource than to follow the line of the Cochituate aqueduct at a safe distance.

The construction of a conduit on this line cannot meet with as many objections as it did formerly when it was a

question of building an additional aqueduct from Lake Cochituate to Chestnut-hill reservoir, because the most objectionable portion of the route, *i. e.* from the lake to Dedman's brook, is not to be considered. It would be, however, an unsatisfactory and expensive undertaking.

The line has been so located as to avoid the immediate vicinity of the aqueduct, and enough margin has been left, in any case, not to endanger its safety during construction.

The cost of the conduit is \$1,608,000.

The cost of improving the water-shed of Morse's pond is consequently as follows:—

Reservoirs and gate-houses	\$420,197
Main conduit	1,608,000
Total	\$2,028,197
The cost of works on the Cochituate water-shed is	\$274,814
Expenditure necessary to secure an average supply of 20,000,000 gallons per day in a year of drought	\$2,303,011

The amount of work to be performed to obtain that result is large; it includes the raising of Lake Cochituate, the construction of seven reservoirs, of a conduit and gate-houses, and 200,000 cubic yards of earth must be applied to the regrading of roads; it has been found impossible to so utilize the storage room to be found in Morse's pond water-shed as to save the water which is wasted at the overflow of Lake Cochituate, and it must be remembered that many features of the complicated and expensive scheme hereinbefore described have been found very objectionable. Some of them might have been eliminated, but the available water supply would have been lessened, and it has been deemed proper, in the

present circumstances, to show the *extreme limits* of the capacity of the water sources.

Another plan, however, might be suggested, by which an additional supply could be procured at a considerably smaller cost, sufficient to secure a constant flow of 17,000,000 gallons in the Cochituate conduit in a dry year.

Nothing, in this case, would be done in the water-shed of Lake Cochituate; the level of Nonesuch pond, which drains nearly three square miles, would be raised $22\frac{1}{2}$ feet above its present surface, and a large reservoir of 1,700,000,000 gallons would be formed; the natural flow of a portion of the drainage area of Stevens' brook would also be utilized. An additional water-shed of 4.40 square miles would thus be secured.

In a dry year the contents of the storage basin, combined with the natural flow of the available water-shed, would furnish a total volume of 2,518,000,000 gallons, which, being distributed throughout the year, would more than compensate for the deficiency of the supply from Lake Cochituate.

If the dry year were to be followed by a series of eight years during which the average amount of rainfall collected would not be above 16 inches, as has been the case once, before the construction of the Cochituate water works, the additional water-shed and storage reservoir combined, could keep up the supply of 17,000,000 gallons per day.

The water of Stevens' brook being of a superior quality, probably no inconvenience would be felt from the fact that a large proportion of it would enter the conduit without first having been purified by storage.

The proposed reservoir is supposed to be connected with the Cochituate conduit by means of an intermediate reservoir of small capacity, built on Stevens' brook, and a proper system of gates and overflow.

The cost of the reservoir and appurtenances is estimated at \$210,000.

NOTE. — The estimates do not take into account the mill damages.

SEWERAGE OF NATICK.

Reference has been made, in another part of this report, to a system of sewerage for the town of Natick.

This question has been investigated, at your request, and some surveys have been made to find the best location, and estimate the cost of a sewer of sufficient capacity to divert from Lake Cochituate the sewage of the town.

The investigation has been limited to the most thickly populated portion, situated at the south end of the lake.

The drainage of Natick is conveyed to Lake Cochituate by two principal channels, viz.: Pegan's brook and the eastern tributary of Dug pond. A plan was proposed, in 1864, for diverting Pegan's brook into Bannister's brook through a brick sewer, 3 feet in diameter, 14,000 feet long, and built around the lake; but the town has grown since, and the introduction of water will soon increase the volume of its sewage;* consequently, a complete system of sewerage ought to include, beside Pegan's brook, the eastern tributary of Dug pond, which flows through a district already much built upon.

The diverting of this brook, however, is much more important for Natick than for Boston, because the sewage matter conveyed by it flows into Dug pond, near the point where the pumping engines are to be established, thus endangering the purity of the water-supply of the town; for Boston, the circumstances are different. The water-supply of Natick being derived from the pond, the amount of water that will hereafter flow from Dug pond into Lake Cochituate will be small, and that small quantity, if polluted, will be diluted and purified to a large extent by its passage from the south end of the lake to the gate-house.

Consequently, it may be said that both brooks must be

* The water supply will be taken from Dug pond; the works are in course of construction.

diverted: Pegan's brook, to secure the purity of the water of the lake; and the eastern tributary of Dug pond, to prevent the pollution of the water supply of Natick.

It has been deemed proper to provide a single channel for diverting the two streams, and the sewage is to be discharged into Bacon's brook, a tributary of Charles river, which it meets a short distance above South Natick.

The water-shed of Pegan's brook has an area of 265 acres, 75 of which are below the level of the proposed sewer and must continue to drain into the lake.

The portion of the water-shed of Dug pond which should be diverted is equal to 480 acres; the rest is very sparsely inhabited, and will not probably be built upon for many years.

Thus the amount of water-shed which would be withdrawn from the lake is equal to 670 acres.

Various routes have been examined for the location of the sewer. The first, the lowest and the most satisfactory for a complete drainage is connected with Pegan's brook below the gas works, then follows Washington avenue, Maple and Waban streets, crosses Main and Cottage street near Walcott street, then Woodland street, thence to Bacon's brook. The excavations are deep on that line; a large amount of rock would be encountered, and the estimated cost is above \$150,000.

The cost of the above plan being very high, another has been studied, in which the starting point has been taken five feet higher; it excludes from the sewered territory a small area, the drainage of which is, unfortunately, of an objectionable character, the district being thickly populated, and containing some manufacturing establishments, among which are the gas-works. The latter, however, might be so altered, at a small cost, as to drain their refuse into the proposed sewer.

This route, via Spring, Plain and Main street, can be followed at less cost; the excavations are of a more satisfactory character, and it is thought to be the most desirable.

A brick sewer, three feet in diameter, has been adopted for the first and shorter portion of the proposed line, with a descent of one foot per 1,000 feet ; for the balance of the line the diameter of the sewer is increased to five feet with an inclination of two feet in a thousand.

The estimated cost is \$107,000, not including land damages.

If it was found advisable to limit the sewerage of Natick to the water-shed of Pegan's brook, according to the course followed by the City Engineer in 1864, the cost of a three-foot sewer, constructed on the same route as recommended for a more comprehensive plan, would be \$85,400.

Respectfully submitted,

A. FTELEY,

Resident Engineer.

APPENDIX B.

REPORT

OF

MR. D. W. CUNNINGHAM,

ON

INCREASING THE SUPPLY FROM

MYSTIC LAKE.

APPENDIX B.

OFFICE OF BOSTON WATER WORKS, ADDITIONAL SUPPLY,
SOUTH FRAMINGHAM, August 21, 1874.

JOSEPH P. DAVIS, ESQ., *City Engineer*: —

SIR: About the last of June you instructed me to make surveys of the lower Mystic pond, and lands that would be covered by flowing to the height authorized by an act of the Legislature of June 25th, this year; to locate the dam and make an estimate of the cost of such flowage; also to re-examine all the valley as to its capability for storage, and the relation between the drainage area and capacity of each storage basin, with a view to ascertaining the quantity of water which may be obtained in a year of drought, for use in Boston; also to present a scheme to you with estimates of cost of the works to get the supply to Boston, and to furnish you with any facts I might obtain bearing upon the subject.

Owing to the variety of other work given to the engineers of the "Additional Supply" at this time, only a small party was available for these surveys, and the time necessarily occupied in procuring information, facts and statistics will account for my inability to report to you sooner.

I hand you, with this, plans, showing flowage of the lower Mystic, the North Woburn storage basins, and a plan of a part of the Lowell Railroad, with profile, showing how it would be damaged by building the large reservoir on the Abajonna river, and two schemes for its protection.

In order to plan a scheme of works, it becomes necessary, first, to ascertain what quantity of water may be at *all times* available; this involves a knowledge of the least rainfall and percentage collectable.

It will, however, be superfluous for me to demonstrate, by a list of the dry years recorded in the neighboring towns, that for a year of drought we may not count on more than 30 inches of rainfall, and that but 40 per cent. of this can be collected for use.

I shall therefore consider that this point has already been proved, and assume that 12 inches of annual rainfall is the yield of the district in a year of drought.

The drainage area of the upper Mystic, as found by accurate survey, is 27.75 square miles; to obtain the quantity of water which may be had from this area, without the lower pond, we will deduct the area of the water surfaces, or 1.58 square miles, and there remain 26.17 square miles; 12 inches of water on this area is equal to 5,457,632,400 gallons annually. This would be equal to 14,952,418 gallons per day.

The storage capacity necessary to utilize this amount must be equal to 1,690,208,272 gallons, or to a supply for 113 days, as shown by table, page 67.

All the proposed storage reservoirs in the valley draining into the *upper Mystic* have an aggregate capacity of 2,668,908,476 gallons; the difference between these two quantities, minus the surplus storage in the Winchester Water Works reservoir (which is not under the control of the city), is 747,022,850 gallons, which will furnish a daily supply of 2,046,638 to add to the rainfall in a dry year; therefore $14,952,418 + 2,046,638 = 16,998,056$ gallons, which will be the total yield of the upper Mystic with all the storage in a year of drought.

The drainage area of the *lower Mystic pond*, as ascertained by approximate survey, is 5.63 square miles; this added to that of the upper pond gives 33.38 square miles, deducting

from which the water surfaces of all the ponds and proposed reservoirs, or 2.18 square miles, and there remain 31.20 square miles, as the total available area of water-shed. Twelve inches of water on this area is equal to 869,849,640 cubic feet, or 6,506,475,307 gallons, annually. This will furnish a daily quantity of 17,825,960 gallons, providing the storage capacity is sufficient to utilize the surplus of the rainy months.

The storage capacity necessary to utilize this quantity of water must be equal to 2,078,673,517 gallons, or to a supply for 116 days.

All the reservoirs which can be built in the whole valley have a total storage capacity of 3,426,317,142 gallons; this will admit of carrying over from the average year for use in the dry year 3,426,317,142 — 2,078,673,517 (less the surplus storage of the Arlington and Winchester Water Works reservoirs, which are not under control of the city), or 926,144,720 gallons; an additional daily supply of 2,537,383 gallons.

If, therefore, all the storage reservoirs shown in the accompanying schedule are built, we may estimate the daily yield of the whole Mystic valley, including both the upper and lower ponds, as $17,825,960 + 2,537,383$ gallons, or 20,363,343 gallons per day.

Tables showing Areas and Capacities of Basins in Mystic Valley.

No.		WATER AREA.	TOTAL CAPACITY.	DRAIN'GE AREA.	CONDITION OF BASIN ON Nov. 1st.
		<i>Acres.</i>	<i>Cubic feet.</i>	<i>Sq. miles.</i>	<i>Cubic feet.</i>
1	West Branch	43	16,711,200	2.82	3,000,000 left in.
2	" "	112	48,732,620	3.36	10,000,000 " "
3	Horn pond	144	37,408,640	1.24	Drawn down.
4	East Branch	46	20,415,900	2.00	7,000,000 left in.
5	" "	36	16,150,570		
6	" "	323	137,637,016	9.69	45,000,000 " "
7	Upper Mystic lakes and Winter pond	246	44,987,000	7.93	Drawn down.
	Winchester Water Works	60	34,763,000	0.71	
8	Lower Mystic lake and Mill ponds in Arlington . . .	181	37,621,450	2.51	Drawn down.
	Two Arlington reservoirs	204	63,636,363	3.12	21,200,000 left in.
		1,395 acres.			
		2.18 sq. miles.	458,063,789	33.38	86,200,000 left in.

The following tables have been prepared to show the action of the storage basins, and the relation of their capacity to the drainage area, and the service which they perform during the months of drought. The proportion flowing off is assumed from the proportion observed to have flowed off for each month, during the year of greatest drought, recorded both in the Cochituate and in the Croton valleys: —

THE UPPER MYSTIC AND THE EAST AND WEST BRANCH BASINS. — (See preceding page.)

SHOWING MONTHLY CONDITION IN A YEAR OF DROUGHT. WATER UTILIZED ASSUMED AT 12 INCHES.
 (Water area 1.68 square miles. Water shed area = 27.75 square miles. Available rainfall equal to 729,630,000 cubic feet, or 6,457,632,400 gallons per year, or 14,952,418 gallons per day.)

MONTHS.	WATER FLOWING OFF. ASSUMED.	AMOUNT OF RAINFALL COLLECTED FOR THE MONTH.	AMOUNT APPLIED TO USE.	AMOUNT APPLIED TO STORAGE.	AMOUNT DRAWN FROM STORAGE.	AM'T OF WATER IN STORE. TOTAL STORAGE CAPACITY, 366,805,946 CU. FEET.	SURPLUS STORAGE.
	Inches.	Cubic Feet.	Cubic Feet.	Cubic Feet.	Cubic Feet.	Cubic Feet.	
January	1.36	82,688,968	75,596,964	7,092,004		125,617,560	
February	1.68	102,148,230	70,941,925	31,206,275		156,823,935	
March	1.60	97,251,568	64,397,144	32,854,421		189,708,359	
April	1.20	72,063,000	51,435,015	21,524,085		211,232,444	
May	1.12	68,103,664	53,372,431	14,731,230		225,963,674	130,842,272 .
June	0.40	24,318,568	53,165,697		34,847,129	191,116,545	30,972,907 Winchester Works.
July	0.24	14,592,600	63,696,218		49,067,618	142,048,927	99,869,365 cu. feet per year.
August	0.40	24,318,568	63,696,403		39,370,835	102,678,092	747,022,850 galls. per year.
September	0.48	29,185,200	59,216,771		30,031,571	72,646,521	2,046,638 galls. per day.
October	0.80	48,644,432	53,290,953		7,646,521	65,000,000	14,952,418 galls. per day.
November	1.44	87,555,800	52,642,805	34,912,795		99,912,795	16,998,056 galls. per day.
December	1.28	77,829,632	59,216,771	18,612,861		118,525,656	
				65,000,000			
				118,525,656			

TOTAL UPPER AND LOWER MYSTIC BASINS. — (See page 66.)

SHOWING MONTHLY CONDITION IN A YEAR OF DROUGHT. WATER UTILIZED ASSUMED AT 12 INCHES.
 (Water area, 2.13 sq. miles. — Water-shed area, 33.38 sq. miles. — Available rainfall equal to 869,849,640 cubic feet, or 6,506,475,307 gallons per year, or 17,825,960 gallons per day.)

MONTHS.	WATER FLOWING OFF, ASSUMED.	AMOUNT OF RAINFALL COLLECTED FOR THE MONTH.	AMOUNT APPLIED TO USE.	AMOUNT APPLIED TO STORAGE.	AMOUNT DRAWN FROM STORAGE.	AM'T OF WATER IN STORE. TOTAL STORAGE CAPACITY 458,063,789 C. FT.	SURPLUS STORAGE.
	Inches.	Cubic feet.	Cubic feet.	Cubic feet.	Cubic feet.	Cubic feet.	
January	1.36	98,580,060	90,125,121	8,454,939		153,267,108	
February	1.68	121,778,950	84,575,480	37,203,470		195,470,578	
March	1.60	115,977,032	76,772,929	39,204,123		234,674,701	
April	1.20	86,984,964	61,324,400	25,660,564		200,335,265	
May	1.12	81,191,765	63,629,501	17,562,264		277,897,529	180,166,260
June	0.40	28,962,988	70,536,107		41,544,019	236,353,510	56,350,121 Win. & Arl. W'ks.
July	0.24	17,396,993	75,894,381		58,497,383	177,856,122	123,816,139 c. ft. per year.
August	0.40	28,992,089	75,924,175		46,937,086	133,919,036	926,144,720 gallons per year.
September	0.48	34,793,986	70,596,997		33,805,011	95,116,025	2,537,383 " " day.
October	0.80	57,062,875	67,108,900		9,116,925	86,000,000	17,525,960 " " "
November	1.44	104,381,957	62,759,632	41,622,305		127,622,305	20,363,343 " " "
December	1.28	92,756,861	70,596,997	22,159,864		149,812,169	
				86,000,000			
				149,812,169			

In order to estimate what quantity of water may be available, to cross the Charles river, for the use of Boston proper, after deducting the consumption of all the towns now dependent upon it, we must look first at the actual daily consumption.

In 1873, Mystic Works supplied an average daily quantity of	7,755,634
In 1873, Woburn, as given by their Water Board	840,000
In 1873, Arlington, as given by their Water Board	500,000
Average daily gallons	9,095,634

The rate of increase by the Mystic Works previous to 1872 was greater than it probably will be in the future, as the extension into new territory will not continue as rapidly as it has done.

The increase of consumption from 1872 to 1873 was 15 per cent; if we estimate the increase of 1874 as 14 per cent., of 1875 as 12 per cent., and of 1876 as 10 per cent., the consumption of 1876 will be . . . 10,646,232 galls.

The consumption of Woburn for 1876 will be* 1,250,000 “

The consumption of Arlington for 1876 will be 700,000 “

The consumption of Winchester for 1876 will be 350,000 “

The consumption by the fishway from gaugings 500,000 “

Total consumption 13,446,232 “

* The consumption of water in Arlington can hardly be measured by the ordinary consumption per head of population, as they are now supplying about 40 market gardens with water for irrigation through the summer, and I am informed by one of their commissioners, that he has for some days estimated the consumption by farmers for this purpose as high as one million gallons per day. The same is true of Woburn, though to a less extent, the consumption here being very large, owing to the free use of hand-hose for garden purposes.

The quantity available from both ponds				
would therefore be equal to the total				
quantity of	.	.	.	20,363,343 galls.
Less the consumption of	.	.	.	13,446,232 "
				6,917,111 "
Or in case of the upper pond alone, to				
the total quantity of	.	.	.	16,984,301 "
Less the consumption of	.	.	.	12,746,232 "
				4,238,069 "

SEWERAGE AREAS.

A considerable portion of the territory draining into the Mystic ponds will soon require sewerage, and this portion should be deducted from the drainage area which has just been counted upon for a supply of water.

It is a matter of judgment to determine what area of town surface actually needs sewerage; practically it is increasing from year to year, and I have anticipated the present requirements as little as is possible in an approximate estimate of the scheme.

These I have computed to be as follows:—

Woburn Centre . . .	1.61 square miles.
East Woburn . . .	0.25 " "
Cummingsville . . .	0.25 " "
Part of Stoneham . . .	0.90 " "
Part of Winchester . . .	0.30 " "
	3.31 " "

If we suppose the 12 inches available rainfall on this area to be carried off to the sea by the sewers, it would still further reduce the quantity of water available for Boston by 1,890,100 gallons daily, showing as the final result 6,917,111 — 1,890,100 = 5,027,011 gallons.

THE STORAGE RESERVOIRS.

Basin No. 1, at the head of the west branch, has an average depth of about 13 feet on the meadows, and a surface area of 43 acres; about 10 acres of this were formerly Kendall's Mill pond. The changes caused by flowing are 1,550 feet of Lexington street to be regraded, and Cambridge street altered to cross over the dam.

Basin No. 2, just above Horn pond, has a surface area of 112 acres, and will have an average depth of about 14 feet over the meadows. A large part of the bottom is a meadow, from which the muck should be removed.

Changes caused by flowing: one house and two barns to be raised and 2,700 feet of road to be regraded.

Basin No. 3, Horn pond, raised six feet.

It was thought in 1873, when the preliminary examinations were made, that it might not be advisable to raise this pond, on account (among other reasons) of the porous and gravelly nature of its bottom; but on further study of the question and observations of Winter pond, where the case is analogous, this being 12 feet above Horn pond and 20 feet above Wedge pond, with subterranean outlets (probably through this same gravel stratum), I observe, that notwithstanding its very small drainage area, of but $\frac{6}{10} \frac{4}{10}$ square miles, there always remains a good body of water, the fluctuations being only about three feet in the height of its surface; the inference is that the friction in the gravel holds it back, as it would also in Horn pond. Sheet piling being driven the length of the dam and below it would stop the passage through the valley of the stream.

Damage. The principal damage caused is to the ice-houses and railroad tracks of the Boston Ice Co., which would have to be raised three or four feet. I have obtained estimates for raising the houses, from a building-mover of large experience, and from ice-merchants the data necessary to determine the damage on account of ice in store.

The Woburn engine house was built, as Mr. Tidd, the engineer, informs me, with reference to this raising.

Basins No. 4 and 5, in North Woburn, near the head of the east branch, will make excellent storage; the flow line of the upper one having ten feet the greater elevation, its surplus will overflow into the adjoining lower one, requiring for the separation a dam of only 150 feet extreme length. The general depth of the upper basin would be from 12 to 15 feet, and of the lower one about 12 feet.

The only change, except flooding of land, is the removal of a small soap factory.

Basin No. 6, on the *Abajonna river* in East Woburn. Surface area, including Richardson's pond, which is at the same level, 323 acres.

In order to secure sufficient depth of water to make this basin available, we must either suppose the Lowell Railroad to be raised six feet, or else a dyke 4,500 feet long to be built on the east side of the railroad, to dam the waters back from it.

The estimates I have made for raising this section of the railroad amount to \$188,262.

A substantial dyke, and brick drain from the enclosed drainage area, would, I believe, answer the purpose without damage to the railroad, and would cost, by my estimates, \$109,025. The accompanying plan and profile will explain this scheme, which is the one I adopted.

The damage to other property and to roads is quite large in this basin.

6 manufacturing establishments.

17 dwelling-houses.

7 barns.

5,600 lineal feet of common road to be changed.

The general depth in the upper part of this basin, above Salem street, will be from 6 to 10 feet; the depth in the southern half below Salem street, from 8 to 16 feet. I have

estimated for removing a portion of muck, which will slightly increase these depths.

The area of land flowed less than five feet will be 55 acres.

Basin No. 8, Lower Mystic pond, raised $6\frac{1}{2}$ feet.

The area of upland flowed is 17.1 acres, the area of meadow land, 25.5 acres. Total, 42.6 acres.

The most objectionable flowage is that of the meadows of Mill brook, towards the centre of Arlington, where about 10 acres of meadow land will have but from two to four feet of water to cover them. The meadows are quite near to the village, and I first estimated the cost of filling them with gravel for building purposes, but have found it will be more economical and quite as ornamental to remove the muck so as to make a fair depth of water.

The damage to the gas-works, which must be raised about four feet, would be considerable, and the process of raising, while in operation, somewhat expensive. I learn from the superintendent that, owing to small main-pipes, they are now but just able to supply their distant customers on the low lands of Winchester, in a satisfactory manner, their gas-holder at the works being rather light for the purpose; he claims, and I believe justly, that to raise the works would require either larger mains or a heavier holder. In making my estimate of the cost of this item, I have consulted with him as to the details.

Mill brook is the only additional tributary of the lower Mystic of any consequence. This has a drainage area of over five square miles, more than half of which is used for the supply of the town of Arlington; they have one reservoir of 32 acres already built on it and in use, and are now contemplating the project of building another one of 172 acres on the "Great Meadows," so called, higher up on the stream; the object of the increase being, as I learn, principally for the sale of the water to market gardeners for irrigation.

This stream has a very rapid fall, being extensively used for power by the following manufacturing establishments.*

Commencing at the foot, we have,—

The Arlington Gas Works,	0 feet fall
Fowle's Drug Mills, grinding drugs and spices,	19 " "
Cutter's Mills, fancy wood-work	19 " "
Welch & Griffith's saw factory	19 " "
Schouler's print works	19 " "
A. C. Hobbs & Sons, machine shop	19 " "
Theodore Swamb's piano-case factory	19 " "
Charles Swamb's picture-frame factory	34 " "
Lewis' fur-dressing establishment	16 " "
	164 " "

SCHEME OF WORKS.

The brick conduit of the Mystic Water Works will convey about 25,000,000 gallons per day, running under one foot of head at the lake, and the two 36-inch pipes crossing under the river will convey as much; we may therefore consider that the available water is already at the engine house.

The existing engine building was enlarged in 1871, and there is now just room enough to place another 8,000,000 Worthington pump in the south end; but as the building would then be very much crowded, and there would be no room for repairs, and not enough for additional boilers, I have estimated for the enlargement necessary for this purpose.

To increase the pumping capacity, I have, for economical motives and to avoid the expense of a new engine house, estimated for one additional 8,000,000 Worthington engine, as explained above.

A new 30-inch force-main is provided for, leading to a stand-pipe in the reservoir grounds, and thence, by a

* This information, was given me at Cutter's mills.

The elevation of the present Arlington reservoir, as stated to me by one of the Water Commissioners, is 170 feet above mean low water.

30-inch supply-main, via Somerville and Charlestown, to the northerly side of Warren bridge, there connecting with the Boston pipes.

The new pump is intended to pump only into the new force-main; but branch-pipes are so planned with gates, that the existing large engine may be made to pump, as necessity may require, into either force-main.

A stand-pipe is to be so placed that the new 30-inch pipe may be used independently of the reservoir for a Boston supply, or by means of gates may be made to pump into the reservoir for use of any or all of the supply pipes. By the use of the stand-pipe, disconnected from the reservoir, the Mystic water may be made to accommodate itself to the lower pressure in the Boston pipes, without drawing down the head in the Mystic pipes.

DELIVERY OF WATER TO BOSTON.

To ascertain the flowing capacity of the old 20-inch pipe crossing Warren bridge, I have taken a number of observations of the pressure in the Boston and Charlestown main pipes where the connection would be made, at various hours of the day and night, a tabular statement of which accompanies this, and find that with a 30-inch pipe laid through Charlestown, to a point near the bridge, the 20-inch pipe would deliver, with such loss of head as may be considered admissible, from five to seven million gallons per day. By making use of this pipe, a saving is effected of 30 or 40,000 dollars. The works as planned will be available for the increase of consumption north of Charles river.

Record of Gaugings taken upon the Charlestown Main-Pipes and 24-inch Pipe in Union St., Boston.

DATE.	HOUR.	CHARLESTOWN.		BOSTON.	Difference of head in feet.
		On 30 in. main. cor. of Cambridge and Canal. Press. in pounds.	On 16 in. main. City square, cor. of Chelsea street. Press. in pounds.	On 24 in. main. Union. intersect'n of Hanover st. Press. in pounds.	
Friday, June 26	5 P.M.	...	56	...	..
Satur. " 27	7 A.M.	...	56	...	..
" " 27	8½ "	56	...	...	..
" " 27	9.50 "	...	...	38	41.4
Monday, " 29	Midnight	57½	57½	48	21.85
Tuesday, " 30	1 A.M.	...	...	48	21.85
Mon. July 20	8 "	...	53	...	..
" " 20	8.40 "	55	...	...	..
" " 20	9 "	...	...	38	39.1
Satur. Aug. 15	3.20 P.M.	...	...	40	..
" " 15	4.30 "	...	55	...	34.5
" " 15	3.40 "	...	55	...	34.5
" " 15	4.10 "	57	...	...	39.1
Mon. " 17	7.40 A.M.	...	...	38	..
" " 17	8.05 "	...	54	...	36.8
" " 17	8.25 "	56	...	...	41.4

The estimated costs of all the storage basins required to utilize the waters of the Mystic are as follows:—

Storage basin No. 1, on West branch . . .	\$98,976 00
" " " 2, " " . . .	177,915 00
" " " 3, Horn pond raised 6 feet . . .	119,043 00
" " " 4, on East branch . . .	74,594 00
" " " 5, " " . . .	93,014 00
" " " 6, " " . . .	671,936 00
" " " 8, Lower Mystic pond . . .	200,374 00
Total cost of all the basins . . .	\$1,435,852 00

Approximate cost of introducing the water into Boston :—

One 8,000,000 gallon Worthington engine, with alterations and additions to engine house	80,000 00
30-inch force-main, stand-pipe in the reser- voir grounds, gates, check-valves and connections	57,850 00
30-inch cast-iron pipe, from reservoir grounds, to connect with Boston distribution .	255,640 00
	\$393,490 00
Cost of all basins and other works . . .	\$1,829,342 00

Respectfully submitted,

DAVID W. CUNNINGHAM,
Prin. Assistant Engineer, New Supply.

APPENDIX C.

REPORT

OF

MR. A. FTELEY,

ON

WASTE AT THE MYSTIC DAM.

APPENDIX C.

OFFICE OF BOSTON WATER WORKS, ADDITIONAL SUPPLY,
So. FRAMINGHAM, Aug. 22, 1874.

J. P. DAVIS, Esq., *City Engineer*:—

DEAR SIR: Agreeably to the instructions received from you in the beginning of July, I have made some experiments to measure the flow of water from Mystic lake.

Before commencing them, I placed myself in communication with Mr. T. Doane, whose services had been retained by the Mystic Water Board, to investigate the same question. We have worked together, and I am authorized to say, that we agree on the result of the gaugings hereinafter described.

The amount of water distributed and consumed in Charlestown, and the other towns depending upon the former for their supply, has been measured by the working of the pumps. A record of the time during which the pumps are in operation, of the number of pumps at work, and of the number of strokes made by them, is kept at the engine-house; and, having been allowed to consult it, I have derived directly from that source the portion of the yield of the lake which is consumed for domestic purposes.

A considerable proportion of the water which flows from Mystic lake is wasted over the regulating weir located at the head of the conduit near the gate-house. With the exception of certain periods, when no waste could be allowed, on account of scarcity of water, there has been, since the construction of the water works, a constant flow of water over it.

To measure that waste, a temporary weir has been erected at the outlet of the overflow-chamber, and the amount of water corresponding to the various circumstances of the case carefully computed. The record of the working of the pumps, already alluded to, has been again used to take into account the amount of water which is wasted, when pumping is stopped for a time, without any corresponding reduction of the opening of the head-gates.

A large portion, usually the largest, of the water gathered into Mystic lake is wasted every year over the flash-boards connected with the dam. A record of the depth of water over them, when the lake is overflowing, has been kept by the Superintendent of the Mystic Water Works, from day to day since their construction.

From that source, by a system of comparative experiments, has been deduced the amount of water corresponding to the various depths recorded.

The method heretofore used for measuring the depth of water over the flash-boards, and the irregularities resulting necessarily from the friction of water against rough walls and boards which are not intended for accurate measurements, made it desirable to devise a special apparatus, to receive the flow of water and to measure it accurately.

Accordingly, a flume and weir have been built in one of the openings of the dam, of sufficient capacity and tightness to receive the whole of the water flowing through the same opening.

Thus the flow corresponding to each depth of water over the flash-boards has been computed with the following results : —

Depth of water at middle of flash- board.	Flow of water through 5 openings of the dam, in gals. per 24 hrs.	Depth of water at middle of flash- board.	Flow of water through 5 openings of the dam, in gals. per 24 hrs.
$\frac{1}{2}$ inch	1,992,811	5 inches	39,425,333
1 "	5,547,554	5 $\frac{1}{2}$ "	45,619,203
1 $\frac{1}{2}$ "	6,193,871	6 "	50,628,159
2 "	11,903,003	6 $\frac{1}{2}$ "	59,568,877
2 $\frac{1}{2}$ "	13,357,217	7 "	66,516,784
3 "	17,612,136	7 $\frac{1}{2}$ "	74,003,288
3 $\frac{1}{2}$ "	22,782,672	8 "	87,575,944
4 "	25,583,378	9 $\frac{1}{2}$ "	102,441,233
4 $\frac{1}{2}$ "	31,831,109		

The fishway connected with the Mystic dam wastes also every year an amount of water which has been measured in the same manner; to that end, the flow through the fishway has been regulated, as usually done by the Superintendent at various periods of the year, and turned into the gauging flume.

During the experiments, the leakage through the flash-boards and walls of the dam has been so measured as to estimate the waste which takes place in that manner when there is no water overflowing.

The experiments at the dam, commenced on July 13th, have been continued without interruption until the 25th, and have been repeated in each case a sufficient number of times to secure an accurate result; more time has been spent in experimenting on the conduit overflow, etc., and the accuracy of the gaugings has been confirmed by the regularity of the results obtained.

It has been said that the records kept by the Mystic Board have been consulted in some cases. Whenever more information has been found necessary, it has been furnished by the superintendent of the works.

From the results of the experiments above described, the

flow of the Mystic lake can be calculated for any period since the construction of the works; but, understanding that you want, at present, to collect all facts tending to ascertain the yield of its water-shed in a year of drought, I have applied the results of the gaugings to the dryest year on the record, *i. e.* 1871.

Total yield for the year 1871.

	Gallons per year.	Average daily yield in galls.
Flow over dam, including leakage	3,658,757,165	10,023,992
“ at conduit overflow	496,732,690	1,360,911
“ through fish-way	181,892,926	498,337
Amount pumped	1,834,709,550	5,026,602
Surplus in lake at the end of the year	56,747,030	155,471
Totals	6,228,839,361	17,065,313

A daily yield of 17,065,313 gallons represents 12.92 inches of rainfall collected on the whole area of the water-shed.

The rainfall, as recorded by the gauge of the Mystic Water Works, having been equal in 1871 to 29.9 inches, the amount collected was apparently 43.2 % of the total rainfall, which is a large percentage in a year as dry as 1871.

The percentage of rainfall collected during the same year in the water-shed of Lake Cochituate was 32 %.

Had the rainfall in Mystic water-shed been equal to the average of Cambridge, Waltham and Lake Cochituate for the same year, *viz.*, 41 inches, the proportion collected would have been exactly equal to that observed in the water-shed of Lake Cochituate.

It is, consequently, most probable that the total rainfall in the Mystic water-shed, in 1871, was above 29.9 inches.

It may not be out of place to state here that in February and March of this year, I made some preliminary gaugings of

the flow of water from the Mystic lake. The measurements were taken directly at the dam, without any special apparatus and in a summary manner, although some pains were taken to correct by calculation the irregularities which have been entirely eliminated in the last experiments by the construction of a measuring weir. The average daily yield then found for the year 1871 was 17,249,000 gallons.

Respectfully submitted,

A. FTELEY,

Resident Engineer.

APPENDIX D.

REPORT

OF

MR. J. M. MERRICK

UPON THE

*USE OF THE LOWER MYSTIC POND FOR A
STORAGE BASIN.*

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APPENDIX D.

OFFICE AND LABORATORY OF MERRICK & GRAY,
Analytical and Consulting Chemists,
No. 59 Broad Street, Boston, Sept. 26, 1874.

JOS. P. DAVIS, Esq., *City Engineer, Boston*:—

DEAR SIR: I hand you herewith my report containing the results of my analyses of samples of waters and mud-deposits, from the upper and lower Mystic ponds, and the conclusion to which I have been led by these results.

The samples may be divided into five sets, viz.:—

First, 19 samples water received, July 28th, 1874, taken the day previous at the surface of the lower Mystic pond and at each 10 feet of its depth down to 80 feet, together with various other surface samples; second, six samples of mud from the lower Mystic, collected at various depths, August 4th, 1874; third, four samples of mud from the upper Mystic, sent by Mr. Stanwood; fourth, three samples of mud collected by myself, two from the upper and one from the lower Mystic, September 7th, 1874; and fifth, several samples of surface water collected by myself the same day, viz., September 7th. I also received four samples of lower Mystic water on the 3d of September, taken the day before, and which I used to make out the series showing the amount of sulphuretted hydrogen present in the water. In the following statement I have given the number of the sample; the place and time of its collection; a brief notice of its striking properties, if any; and then the analysis in detail; the various analyses being afterwards shown in tabular form, for the purpose of comparison. In making the

analyses I have determined the total residue, the inorganic and organic or volatile constituents, and the amounts of chlorine, sulphuric acid, silica, lime and magnesia present. The alumina and oxide of iron have been determined together. The amount of sulphuretted hydrogen present was determined in separate and fresh samples, taken for the purpose.

Water No. 1. — Surface water of the lower Mystic, collected July 27, 1874.

Nearly colorless. Faint odor. Slight taste. A very little flocculent sediment.

It contained, —

Inorganic matter	47.763	grains to 1 U. S. gallon.		
Organic and volatile matter	9.786	“ “ “		
Total residue	57.549	“ “ “		

The inorganic matter contained, —

Chlorine	17.160	“ “ “		
Sulphuric acid	4.410	“ “ “		
Silica	.292	“ “ “		
Alumina, oxide of iron and phosphates,	1.168	“ “ “		
Lime	4.192	“ “ “		
Magnesia	—	“ “ “		

Water No. 2. — Lower Mystic pond, at a depth of 10 feet, collected July 27, 1874.

Nearly colorless. Inodorous. Faint brackish taste. A little flocculent matter.

It contained, —

Inorganic matter	54.568	grains to 1 U. S. gallon.		
Organic and volatile matter	8.277	“ “ “		
Total residue	62.845	“ “ “		

The inorganic matter contained, —

Chlorine . . .	23.014	grains to 1 U. S. gallon.		
Sulphuric acid . . .	3.594	“ “ “		
Silica	.058	“ “ “		
Alumina, oxide of iron and phosphate . . .	.350	“ “ “		
Lime	6.786	“ “ “		
Magnesia	—	“ “ “		

Water No. 3. — Lower Mystic, 20 feet deep, collected July 27, 1874..

Nearly colorless. Inodorous. Slight brackish taste. Considerable deposit.

It contained, —

Inorganic matter . . .	199.755	grains to 1 U. S. gallon.		
Organic and volatile matter	28.452	“ “ “		
Total residue . . .	228.207	“ “ “		

The inorganic matter contained, —

Chlorine	104.829	“ “ “		
Sulphuric acid . . .	13.756	“ “ “		
Silica	.116	“ “ “		
Alumina, oxide of iron and phosphate . . .	.876	“ “ “		
Lime	6.058	“ “ “		
Magnesia	15.209	“ “ “		

Water No. 4. — From the lower Mystic, at a depth of 25 feet.

Nearly colorless. Strong saline taste. Strong odor of sulphuretted hydrogen. Blackens lead paper promptly.

It contained, —

Inorganic matter . . .	538.678	grains to 1 U. S. gallon.		
Organic and volatile matter	98.154		“	“
			“	“
Total residue . . .	636.832		“	“

The inorganic matter contained, —

Chlorine	278.928		“	“
Sulphuric acid	37.989		“	“
Silica	.292		“	“
Oxide of iron alumina and phosphates	22.393		“	“
Lime	23.301		“	“
Magnesia	5.840		“	“

Water No. 5. — From the lower Mystic, at 30 feet depth, collected July 27, 1874.

Clear when first received. Strong saline taste. Strong smell of sulphuretted hydrogen. On standing deposited sulphur.

It contained, —

Inorganic matter . . .	651.906	grains to 1 U. S. gallon.		
Organic and volatile matter	52.699		“	“
			“	“
Total residue . . .	704.605		“	“

The inorganic matter contains, —

Chlorine	348.611		“	“
Sulphuric acid	29.293		“	“
Silica	33.010		“	“
Alumina, oxide of iron and phosphates	20.524		“	“
Lime	10.194		“	“
Magnesia			“	“

Water No. 6. — From lower Mystic, or depth of 40 feet, collected July 27, 1874.

Yellowish. Saline. Strong smell of sulphuretted hydrogen. Considerable deposit. It deposits sulphur on standing.

It contained, —

Inorganic matter . . .	880.346	grains to 1 U. S. gallon.			
Organic and volatile matter	120.120		“	“	“
	1000.466		“	“	“

The inorganic matter contains, —

Chlorine	457.607	“	“	“
Sulphuric acid	52.738	“	“	“
Silica	9.340	“	“	“

Water No. 7. — Collected July 27, from the upper end of the lower Mystic pond, at a depth of 45 feet.

Clear. Yellowish. Slight deposit. Deposited sulphur on standing. Strong smell of sulphuretted hydrogen. Saline taste.

It contained, —

Inorganic matter . . .	785.232	grains to 1 U. S. gallon.			
Organic and volatile matter	21.617		“	“	“
Total residue . . .	806.849		“	“	“

The inorganic matter contained, —

Chlorine	500.048	“	“	“
Sulphuric acid	43.390	“	“	“
Silica	408	“	“	“
Alumina, oxide of iron and phosphates	63.683	“	“	“
Lime	16.143	“	“	“
Magnesia	3.416	“	“	“

Water No. 8. — From lower Mystic, at a depth of 50 feet, collected July 27, 1874.

Clear. Yellow. Saline. Strong odor of sulphuretted hydrogen. Some flocculent deposit. Deposited sulphur on standing.

It contained, —

Inorganic matter . . .	874.544	grains to 1 U. S. gallon.			
Organic and volatile matter	80.480		“	“	“
Total residue . . .	955.024		“	“	“

The inorganic matter contained, —

Chlorine	486.216		“	“	“
Sulphuric acid	24.793		“	“	“
Silica	.116		“	“	“
Alumina, oxide of iron and phosphates	2.220		“	“	“
Lime	10.398		“	“	“
Magnesia	19.220		“	“	“

Water No. 9. — From lower Mystic, at a depth of 60 feet, collected July 27th, 1874.

Yellowish. Strong saline taste. Flocculent deposit. Strong smell of sulphuretted hydrogen. Deposited sulphur.

It contained, —

Inorganic matter . . .	916.802	grains to 1 U. S. gallon.			
Organic and volatile matter	100.491		“	“	“
Total residue . . .	1017.293		“	“	“

The inorganic matter contained, —

Chlorine	491.347		“	“	“
Sulphuric acid	42.988		“	“	“
Silica	1.517		“	“	“
Alumina, oxide of iron and phosphates	18.578		“	“	“
Lime	15.298		“	“	“
Magnesia	12.157		“	“	“

Water No. 10. — Taken from lower Mystic pond, July 27th, 1874, at a depth of 70 feet. Character that of No. 9.

It contained, —

Inorganic matter . . .	910.820	grains to 1 U. S. gallon.			
Organic and volatile matter . . .	139.648		“	“	“
Total residue . . .	1050.460		“	“	“

The inorganic matter contained —

Chlorine . . .	441.448		“	“	“
Sulphuric acid . . .	79.698		“	“	“
Silica . . .	6.542		“	“	“
Alumina, oxide of iron and phosphates . . .	11.550		“	“	“
Lime . . .	24.687		“	“	“
Magnesia . . .	25.998		“	“	“

Water No. 11. — Water from lower Mystic pond, at a depth of 80 feet, July 27th, 1874.

Yellowish. Some flocculent deposit. Slight smell of sulphuretted hydrogen. Strong saline taste. Became dark brownish and very offensive, on standing six weeks.

It contained, —

Inorganic matter . . .	925.685	grains to 1 U. S. gallon.			
Organic and volatile matter . . .	127.950		“	“	“
Total residue . . .	1053.635		“	“	“

The inorganic matter contained —

Chlorine . . .	464.255		“	“	“
Sulphuric acid . . .	46.774		“	“	“
Silica . . .	,876		“	“	“
Alumina, oxide of iron and phosphates . . .	—		“	“	“
Lime . . .	38.446		“	“	“
Magnesia . . .	—		“	“	“

Water No. 12. — Water collected from the lower Mystic, at a depth of 80 feet, July 27, 1874.

This water was fairly yellowish, with a little flocculent deposit. Clear on standing, with slight smell. It had no smell of sulphuretted hydrogen, and did not become offensive on standing six weeks.

It contained, —

Inorganic matter . . .	917.441	grains to 1 U. S. gallon.			
Organic and volatile matter	119.771		“	“	“
Total residue	1037.212		“	“	“

The inorganic matter contained, —

Chlorine	435.289	“	“	“
Sulphuric acid	65.983	“	“	“
Silica	6.718	“	“	“
Alumina, oxide of iron and phosphates	9.640	“	“	“
Lime	40.776	“	“	“
Magnesia	19.849	“	“	“

It is worthy of notice that while the two waters, Nos. 11 and 12, are taken at the same depth, 80 feet, and while they are about alike in the amount of total residue and chlorine, they are essentially unlike in their behavior on standing in the laboratory, — No. 11 becoming brown and turbid, and having from the first, a sensible odor of sulphuretted hydrogen; while No. 12 was, at the end of six weeks, about as it was when first collected, — nearly free from smell, clear, and having only a slight flocculent deposit.

Water No. 13. — This was a sample of water from the lower end of the lower Mystic pond, at a depth of 85 feet, collected July 27, 1874.

It was thick. Turbid. Brackish from suspended matter, with a strong smell of sulphuretted hydrogen.

It contained, —

Inorganic matter . . .	1356.440	grains to 1 U. S. gallon.
Organic and volatile matter	210.330	“ “ “
Total residue . . .	1566.770	“ “ “
Of which the matter in suspension was . . .	419.722	“ “ “

The inorganic matter contained, —

Chlorine	388.480	“ “ “
Sulphuric acid	49.667	“ “ “
Silica	large am't.	
Alumina, oxide of iron and phosphates . . .	56.763	“ “ “
Lime	36.616	“ “ “
Magnesia	3.906	“ “ “
Free sulphuretted hydrogen	140.610	cubic in. to 1 cub. foot.
Combined “ “ . . .	24.085	“ “ “

Water No. 14. — This, according to the statement of the collectors, was essentially a duplicate of No. 13, being collected at a depth of 85 feet.

It was thick, black, full of suspended matter, with of course a strong saline taste, and a strong smell of sulphuretted hydrogen.

It contained, —

Inorganic matter . . .	881.210	grains to 1 U. S. gallon.
Organic and volatile matter	124.155	“ “ “
Total residue . . .	1005.365	“ “ “
Of which the matter in suspension was . . .	202.093	“ “ “

The inorganic matter contained, —

Chlorine . . .	443.685	grains to 1 U. S. gallon.		
Sulphuric acid . .	59.363	“ “ “		
Silica	—	“ “ “		
Alumina, oxide of iron and phosphates .	150.268	“ “ “		
Lime	35.650	“ “ “		
Magnesia . . .	3.651	“ “ “		

Water No. 15. — Water collected at outlet of lower Mystic pond, a little after low tide, July 27, 1874.

Nearly colorless, or very faintly yellow. Slight odor and somewhat brackish taste. Trifling sediment.

It contained, —

Inorganic matter . .	51.414	grains to 1 U. S. gallon.		
Organic and volatile mat- ter	38.561	“ “ “		
Total residue .	89.975	“ “ “		

The inorganic matter contained, —

Chlorine . . .	22.545	“ “ “		
Sulphuric acid . .	9.012	“ “ “		
Silica	.292	“ “ “		
Alumina, oxide of iron and phosphates .	1.460	“ “ “		
Lime	5.242	“ “ “		
Magnesia . . .	2.105	“ “ “		

Water No. 16. — Sample collected from the surface at the upper end of the lower Mystic pond, July 27, 1874.

Clear. Nearly colorless. Faint odor. Brackish taste. Slight sediment.

It contained, —

Inorganic matter . . .	44.403	grains to 1 U. S. gallon.		
Organic and volatile matter	7.011		“	“
			“	“
Total residue . . .	51.414		“	“

The inorganic matter contained, —

Chlorine	9.452		“	“
Sulphuric acid	3.258		“	“
Silica	1.752		“	“
Alumina, oxide of iron and phosphates	4.089		“	“
Lime	6.552		“	“
Magnesia	2.631		“	“

Water No. 17. — Sample of water collected from the lower Mystic pond at the outlet of Mill Brook, July 27, 1874.

Colorless. Tasteless and inodorous.

It contained, —

Inorganic matter . . .	3.505	grains to 1 U. S. gallon.		
Organic and volatile matter	2.921		“	“
			“	“
Total residue . . .	6.426		“	“

The inorganic matter contained, —

Chlorine	.449		“	“
Silica, alumina, oxide of iron and phosphates	5.258		“	“

This sample was collected at my request, to show by comparison the character of the water flowing in from the brook. It seems a reasonably good water.

Water No. 18. — Sample from the outlet of the lower Mystic pond, a little after high tide, collected July 27, 1874.

Colorless. Brackish taste. Inodorous, or with but a faint smell.

It contained, —

Inorganic matter . . .	47.616	grains to 1 U. S. gallon.
Organic and volatile matter	11.685	“ “ “
Total residue . . .	59.301	“ “ “

The inorganic matter contained, —

Chlorine	21.306	“ “ “
Sulphuric acid	5.647	“ “ “
Silica	2.044	“ “ “
Alumina, oxide of iron and phosphates . . .	3.145	“ “ “
Lime	9.465	“ “ “
Magnesia	1.444	“ “ “

Determinations of the amount of free sulphuretted hydrogen in the lower Mystic pond were made by myself upon four samples taken respectively at depths of 20, 30, 40, and 50 feet, Sept. 2, 1874, and delivered to me early the next morning; and at the pond by myself on the 7th of Sept., 1874. On this last occasion samples were taken at the surface, and at 5, 10, 15, and 70 feet. The determinations were made promptly, with a graduated solution of iodine, and gave very curious results. By reference to a diagram appended to this report, it will be seen that the amount of free sulphuretted hydrogen in the water at the lower Mystic is barely perceptible till we reach a depth of 20 feet. Then it is marked, and increases rapidly down to 50 feet, when it diminishes to 70 feet, the level of the lowest sample taken for this purpose. (“The upper limit of the sulphurous stratum,” says Prof. Horsford, in 1860, “was very precisely nineteen feet and nine inches from the surface.”) The actual amount of sulphuretted hydrogen gas in the water is as follows: —

At the surface	.	1.14	cub. inches to one cub. foot.
" 5 feet	. .	1.14	" " " " " "
" 10 "	. .	1.14	" " " " " "
" 15 "	. .	.76	" " " " " "
" 20 "	. .	11.40	" " " " " "
" 30 "	. .	31.95	" " " " " "
" 40 "	. .	65.42	" " " " " "
" 50 "	. .	116.21	" " " " " "
" 70 "	. .	95.00	" " " " " "

The shaded diagram given in connection with this report shows graphically the relation of the sulphuretted hydrogen to the water, and it cannot fail to be observed how enormous is the increase between 20 and 50 feet in depth. It might be said that, so far as this gas is concerned, there is a *comparatively* pure stratum of water until we get to 20 feet — nineteen feet and nine inches (Horsford) — when it suddenly becomes largely charged with this offensive gas.

An attempt was made to determine the amount of sulphuretted hydrogen — if any could be found — in the water of the upper Mystic; but its presence could not be recognized either by the smell, or by the iodine test.

I give below the detailed analyses of 13 samples of mud, or deposits from the bottom of the lower and upper Mystic ponds. They may be divided into three sets, viz.: First, six samples of mud taken from the lower pond, Aug. 4, 1874, and delivered to me the next day but one, and one sample taken by myself, Sept. 7. These samples were taken from depths of 35, 40, 65, and 70 feet. In the analysis their general character was noted, and in them were determined the amount of water, of dry matter, of inorganic and volatile matter, of silica, etc. (and these results have also been calculated on the dry residue), and the cubic inches of free and combined sulphuretted hydrogen contained in a cubic foot of the mud. By free sulphuretted hydrogen gas is meant that which can be derived from the mud by simple

boiling; while by combined gas is meant that which can be eliminated by a boiling temperature aided by a strong acid. The method I have employed consists in passing the gas derived from a given amount of mud into a solution of acetate of lead rendered acid by pure acetic acid, — this precaution being very necessary in order to make sure that no carbonate is precipitated, — converting the resultant sulphide into sulphate of lead, weighing it as such, and reckoning from this the weight of sulphydric acid. It was my intention to make determinations of nitrogen in the dry residue from each of the muds, but lack of time prevented my so doing. I regret this, as I think the information that might have been obtained in regard to the nitrogenous constituents of these deposits would have been of interest and value.

Mud No. 1. — This was collected from the lower Mystic pond, at a depth of 35 feet. It was a thin mud, darkening lead paper at ordinary temperatures.

It contained, —

Water	90.98 per cent.
Inorganic matter	6.86 “ “
Organic and volatile	2.16 “ “
	100. “ “

The inorganic matter contained, —

Silica, oxide of iron, etc.	5.710 per cent.
Chlorine	.147 “ “
Free sulphuretted hydrogen	traces.
Combined “ “	157.07 cub. in. to 1 cub. ft.

In other words, 100 parts of the dry mud contained, —

Silica	63.30 per cent.
Organic and volatile matter	23.94 “ “
Chlorine	1.63 “ “
Alumina, salts and matters not determined	11.13 “ “
	100. “ “

Mud No. 2. — This was a sample collected from the lower Mystic pond, at a depth of 40 feet.

A thin mud, darkening lead paper faintly on application of heat.

It contained, —

Water	91.21	per cent.
Inorganic matter	6.50	“ “
Organic and volatile matter	2.29	“ “
	100.	“ “

The inorganic matter contained, —

Silica, oxide, iron, etc.	5.36	“ “
Chlorine	.228	“ “
Free sulphuretted hydrogen	traces.	
Combined “ “	224.41	cubic in. to 1 cubic foot.

In other words, 100 parts of dry mud contain —

Silica, etc.	60.97	per cent.
Organic and volatile matter	26.05	“ “
Chlorine	2.59	“ “
Alumina and undetermined matter	10.39	“ “
	100.	“ “

Mud No 3. — This was taken from the lower Mystic pond, at a depth of 40 feet.

It was a thick offensive mud, giving off perceptible hydro-sulphuric acid, at ordinary temperatures.

It contained, —

Water	86.11	per cent.
Inorganic matter	10.96	“ “
Organic and volatile matter	2.93	“ “
	100.	“ “

The inorganic matter contained, —

Silica, oxide of iron, etc.	9.31	per cent.
Chlorine	.245	“ “
Free sulphuretted hydrogen	455.06	cub. in. to 1 cub. ft.
Combined “ “	203.24	“ “ “
Total	458.30	“ “ “

In other words, 100 parts dry must contain, —

Silica, etc.	67.02	per cent.
Organic and volatile matter	21.09	“ “
Chlorine	1.74	“ “
Alumina and undetermined matter	10.15	“ “
	100.	

Mud No. 4. — This was a rather thin mud, collected from the lower Mystic pond, at a depth of 40 feet.

It gave evidence of the presence of free sulphuretted hydrogen in some quantity.

It contained, —

Water	90.02	per cent.
Inorganic matter	8.00	“ “
Organic and volatile matter	1.98	“ “
	100.	“ “

The inorganic matter contained, —

Silica, oxide of iron, etc.	7.04	“ “
Chlorine	.089	“ “
Free sulphuretted hydrogen	149.61	cub. in. to 1 cub. ft.
Combined “ “	33.21	“ “ “
Total	182.82	“ “ “

In other words, 100 parts of dry mud contain, —

Silica, etc.	70.54	per cent.
Organic and volatile matters	19.84	“ “
Chlorine	.79	“ “
Alumina and matters undetermined	8.83	“ “
	100.	“ “

Mud No. 5. — This was a sample of mud collected from the lower Mystic pond, at a depth of 65 feet.

It was a thin, not specially offensive mud, darkening lead paper very faintly at ordinary temperatures.

It contained, —

Water	92.23 per cent.
Inorganic matter	6.06 “ “
Organic and volatile matter	1.71 “ “
	100. “ “

The inorganic matter contained, —

Silica, oxide of iron, etc.	4.79 “ “
Chlorine	.317 “ “
Free sulphuretted hydrogen	traces.
Combined “ “	214.96 cub. in. to 1 cub. ft.

In other words, 100 parts of dry mud contain, —

Silica, etc.	61.64 per cent.
Organic and volatile matter	22.00 “ “
Chlorine	4.08 “ “
Alumina and matters undetermined	12.28 “ “
	100. “ “

Mud No. 6, A. — This was a thin, somewhat offensive mud, collected from the lower Mystic pond, at a depth of 70 feet. Darkening lead paper, at ordinary temperature, and like some of the others very strongly on application of heat.

It contained, —

Water	88.33 per cent.
Inorganic matter	9.39 “ “
Organic and volatile matter	2.28 “ “
	100. “ “

The inorganic matter contained, —

Silica, oxide of iron, etc.	7.81 “ “
Chlorine	.14 “ “
Free sulphuretted hydrogen	211.174 cub. in. to 1 cub. ft.
Combined “ “	167.114 “ “ “
Total	378.228 “ “ “

In other words, 100 parts of dry mud contain, —

Silica	66.92 per cent.
Organic and volatile matter	19.45 “ “
Chlorine	1.19 “ “
Alumina and matters undetermined	12.44 “ “
	100. “ “

Mud No. 6, B. — This was collected by myself on September 7th, 1874, from the middle of the lower Mystic pond, at a depth of 85 feet.

It had a perceptible odor of sulphuretted hydrogen.

It contained, —

Water	88.00 per cent.
Inorganic matter	9.47 “ “
Organic and volatile matter	2.53 “ “
	100. “ “

The inorganic matter contained, —

Silica	7.82 “ “
Alumina, with some oxide of iron, etc.	.398 “ “
Chlorine and sulphuric acid	considerable amount.
Free sulphuretted hydrogen	traces.
Combined “ “	249.08 cub. in. to 1 cub. ft.

In other words, 100 parts dry mud contain, —

Silica	65.16 per cent.
Organic and volatile matter	21.08 “ “
Alumina, oxide of iron, etc.	3.31 “ “
Salts and matters undetermined	10.45 “ “

Muds No. 7—10. — Muds Nos. 7 to 10 inclusive were collected from the upper Mystic pond, at various depths, on August 11, 1874.

No. 7. — This was from a depth of 18 feet; and was a mud of no offensive peculiarities.

It contained, —

Water	84.86	per cent.
Inorganic matter	12.71	“ “
Organic and volatile matter	2.43	“ “
	100.	“ “

The inorganic matter contained, —

Silica	12.18	“ “
Alumina, with some oxide of iron, etc.	.393	“ “
Chlorine	.009	“ “
Free sulphuretted hydrogen	traces.*	
Combined “ “	“ *	

In other words, 100 parts of dry mud contain, —

Silica	80.44	per cent.
Organic and volatile matter	16.05	“ “
Alumina, oxide of iron, etc.	2.60	“ “
Salts and matters not determined	.91	“ “
	100.	“ “

Mud No. 8. — This was collected from the upper pond, at a depth of 58 feet.

It was not offensive *per se*, but evolved sulphuretted hydrogen abundantly, when heated with a strong acid.

It contained, —

Water	86.45	per cent.
Inorganic matter	10.40	“ “
Organic and volatile matter	3.15	“ “
	100.	“ “

The inorganic matter contained, —

Silica	7.85	“ “
Alumina, with some oxide of iron, etc.	.185	“ “
Chlorine	slight amount.	
Free sulphuretted hydrogen	1.398 cub. in. to 1 cub. ft.	
Combined “ “	465.810	“ “ “

Total	467.108	“ “ “
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* Not sufficient to determine quantitatively in 48 grammes of the wet mud.

In other words, 100 parts of dry mud contained, —

Silica	57.92 per cent.
Organic and volatile matter	23.24 “ “
Alumina, oxide of iron, etc.	1.36 “ “
Salts and matters not determined	17.48 “ “
	100. “ “

Mud No. 9. — This was collected from the upper Mystic pond, at a depth of 60 feet.

It smelled of sulphuretted hydrogen, but not very strongly.

It contained, —

Water	88.41 per cent.
Inorganic matter	9.58 “ “
Organic and volatile matter	2.01 “ “
	100. “ “

The inorganic matter contained, —

Silica	8.80 “ “
Alumina, with some oxide of iron, etc.	.393 “ “
Free sulphuretted hydrogen	traces.
Combined “ “	261.81 cub. in. to 1 cub. ft.

In other words, 100 parts of dry mud contain, —

Silica	76.19 per cent.
Organic and volatile matter	17.54 “ “
Alumina, oxide of iron, etc.	3.38 “ “
Salts and matters not determined	3.09 “ “
	100. “ “

Mud No. 10. — This was taken from the upper Mystic pond, at a depth of 77 feet, Aug. 11, 1874.

It was a thin mud, not offensive.

It contained, —

Water	89.53 per cent.
Inorganic matter	7.94 “ “
Organic and volatile matter	2.53 “ “

100. “ “

The inorganic matter contained, —

Silica	7.20 “ “
Alumina, with some oxide of iron, etc.	.48 “ “
Chlorine	slight
Free sulphuretted hydrogen	traces.
Combined “ “	97.24 cub. in. to 1 cub. ft.

In other words, 100 parts of dry mud contained, —

Silica	68.76 per cent.
Organic and volatile matters	24.16 “ “
Alumina, oxide of iron, etc.	4.58 “ “
Salts and matters not determined	2.50 “ “

100. “ “

Mud No. 11. — This and the following sample were taken under my supervision Sept. 7, 1874.

No. 11 was dredged from Bacon's bridge. It was a gravelly mud, with no offensive peculiarities.

It contained, —

Water	86.81 per cent.
Inorganic matter	10.93 “ “
Organic and volatile matter	2.26 “ “

100. “ “

The inorganic matter contained, —

Silica	10.34 “ “
Alumina, with some oxide of iron, etc.	.405 “ “
Chlorine	traces.
Free sulphuretted hydrogen	traces.*
Combined “ “	“

* 31.50 grammes of the wet mud did not give enough gas to determine.

In other words, 100 parts of dry mud consist of, —

Silica	78.40 per cent.
Organic and volatile matter	17.14 “ “
Alumina, oxide of iron, etc.	3.07 “ “
Salts and matters not determined	1.39 “ “
	100. “ “

Mud No. 12. — This was taken from about the middle of the upper Mystic, Sept. 7, 1874, at a depth of about 80 feet. It was not offensive to the smell.

It contained, —

Water	88.54 per cent.
Inorganic matter	7.74 “ “
Organic and volatile matter	3.72 “ “
	100. “ “

The inorganic matter contained, —

Silica	7.28 “ “
Alumina, with some oxide of iron, etc.	.289 “ “
Chlorine	slight
Free sulphuretted hydrogen	traces.
Combined “ “	“

In other words, 100 parts of dry mud consist of, —

Silica	63.55 per cent.
Organic and volatile matter	32.44 “ “
Alumina, oxide of iron, etc.	2.52 “ “
Salts and matters not determined	1.49 “ “
	100. “ “

An examination of the figures expressing the results of the analyses of the various samples of mud, does not show, what might perhaps have been expected, some constant ratio between the organic matter and the sulphuretted hydrogen.

To establish such a ratio would probably require the analysis and comparison of a vast number of samples. Again, it may be said that in the lower pond at least, in collecting any specimens of mud deposit for analysis in the future, some means should be devised for getting samples of the surface of the mud, *i. e.*, where it exists in contact with the water, and where the mutual action of the two is of course more energetic. The relation of the free to the combined sulphuretted hydrogen in the different samples is not uniform. This perhaps may be explained by considering that while the action of the saline water is tolerably uniform, producing the combined sulphuretted hydrogen in the form of sulphides of the alkaline bases, yet the large amount of free sulphuretted hydrogen found in certain spots is doubtless due to large amounts of organic sewage matter containing sulphur.

While the decomposition of the sulphates in the salt water and their reduction to sulphides by the organic matters at the bottom of the pond is an active source of the impurity which renders the water of the lower Mystic offensive, yet it should be borne in mind that the inflow of the tide sweeps into the pond a mass of complex filth — decomposing organic and sewage matter — containing a considerable percentage of sulphur compounds. Much further research would be needed to explain the occurrence of exceptionally large amounts of combined sulphuretted hydrogen in the deposits dredged from certain spots at the bottom of the upper Mystic pond.

The general character of the water of the lower Mystic pond may perhaps be best understood by comparing the analytical results I have obtained with an analysis of ordinary sea-water.

The determinations of the amount of total residue, of saline matter in specimens, taken at varying depths from the surface to 80 feet, show that the average character of the water is that of ordinary sea-water diluted with two and one-half

times its bulk of fresh. This dilution, however, is not uniform. The amount of salt water increases with the depth, and very rapidly below the level of 20 feet from the surface.

Below this depth, besides the constituents of sea-water proper, we find diffused large amounts of free sulphuretted hydrogen, rendering the water offensive and totally unfit for domestic purposes. At a depth of 80 feet the amount of saline matter is about one-half that of ordinary sea-water.

Fourteen years ago the water of the lower Mystic was pronounced by high-chemical authority "sufficiently pure at the surface, and for a depth of some 15 feet, to serve the purposes of domestic use." This is not the case at present, the *surface* water giving a total residue of 57.54 grains to the gallon, and one sample, taken at a depth of 10 feet, 62.84 grains, the former being twice the amount found in the surface water in 1860.

The present character of the water may also be seen at a glance by a comparison of one of the foregoing analyses with comparatively recent analyses made by myself of Cochituate water and the water of the Charles river, viz. : —

CHARLES RIVER.	COCHITUATE.	SURFACE LOWER MYSTIC, July 27, 1874,
At Newton, Feb. 19, 1874.	Drawn in Boston, May, 1874.	
Inorganic matter, 1.61* grs. to 1 U. S. gal.	2.10 grs. to 1 U. S. gal.	47.76 grs. to 1 U. S. gal.
Organic and volatile matter . . . 1.22 " " "	.78 " " "	9.78 " " "
Total . . . 2.83 " " "	2.88 " " "	57.54 " " "
Chlorine168 " " "	.20 " " "	17.16 " " "
Sulphuric acid . . .511 " " "	.369 " " "	4.41 " " "

No determinations have been made of the ammonia salts in the lower Mystic water. Some of the deeper specimens,

* Including .23 grs. suspended matter.

however, contain these salts in marked amount, particularly nitrates.

As helping to furnish material for an answer to the questions put to me, several analyses have been made of the water of the upper Mystic pond at the surface, and at depths of 10, 20, 30, and 50 feet.

One (surface) sample was taken July 27, 1874, and sent to me with the samples from the lower pond; the others were taken under my supervision Sept. 7, 1874.

Water No. 1. — This was collected "at the dam of the upper pond" July 27, 1874. It was colorless, tasteless, and inodorous, having in suspension a few almost imperceptible flakes of organic matter.

Analysis showed it to contain, —

Inorganic matter . . .	3.797	grains to 1 U. S. gallon.		
Organic and volatile matter . . .	1.460	"	"	"
Total residue . . .	5.257	"	"	"

The inorganic matter contained, —

Silica	.233	"	"	"
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Water No. 2. — This was collected from Bacon's bridge, Sept. 7, 1874, about one foot below the surface. It was almost colorless, tasteless, and inodorous, depositing a trifling flocculent sediment on standing.

Analysis showed it to contain, —

Inorganic matter . . .	5.258	grains to 1 U. S. gallon.		
Organic and volatile matter . . .	2.160	"	"	"
Total residue . . .	7.418	"	"	"

The inorganic matter contained, —

Chlorine	1.27	"	"	"
Silica, alumina, oxide of iron, etc.	1.16	"	"	"

Water No. 3. — This was taken at the dam, on Sept. 7, 1874, and is practically a duplicate of No. 1 of this series taken six weeks earlier.

It presented the appearance of No. 1.

Analysis showed it to contain, —

Inorganic matter	3.505	grains to 1 U. S. gallon.		
Organic and volatile matter	2.337	“	“	“
Total residue	5.842	“	“	“

The inorganic matter contained, —

Silica, alumina, oxide of iron, etc.	1.300	“	“	“
Chlorine	1.050	“	“	“

Water No. 4. — This sample was taken from the surface of the upper Mystic, about the middle, Sept. 7, 1874. It was colorless, tasteless, and inodorous, leaving, on standing, a very slight sediment.

Analysis showed it to contain, —

Inorganic matter	4.089	grains to 1 U. S. gallon.		
Organic and volatile matter	2.629	“	“	“
Total residue	6.718	“	“	“

The inorganic matter contained, —

Silica, alumina, oxide of iron, etc.	1.927	“	“	“
Chlorine	—	“	“	“

Water No. 5. — This sample was taken Sept. 7, 1874, from the same point as No. 4, but at a depth of 10 feet. It resembled No. 4.

Analysis showed it to contain, —

Inorganic matter . . .	3.797	grains to 1 U. S. gallon.
Organic and volatile matter	2.044	“ “ “
Total residue . . .	5.841	“ “ “

The inorganic matter contains, —

Silica, alumina, oxide of iron, etc.	1.197	“ “ “
Chlorine	1.370	“ “ “

Water No. 6. — This was taken from the same point as No. 4, but at a depth of 20 feet. It resembled No. 4.

Analysis showed it to contain, —

Inorganic matter . . .	4.089	grains to 1 U. S. gallon.
Organic and volatile matter	2.330	“ “ “
Total residue . . .	6.419	“ “ “

The inorganic matter contained, —

Silica, alumina, oxide of iron, etc.	1.752	“ “ “
Chlorine	.974	“ “ “

Water No. 7. — This was taken from the same point as No. 4, but at a depth of 30 feet. It resembled No. 4.

Analysis showed it to contain, —

Inorganic matter . . .	3.970	grains to 1 U. S. gallon.
Organic and volatile matter	1.859	“ “ “
Total residue . . .	5.842	“ “ “

The inorganic matter contained, —

Silica, alumina, oxide of iron, etc.		“ “ “
Chlorine	.807	“ “ “

Water No. 8. — This was collected at the same point as No. 4, but at a depth of 50 feet. It resembled No. 4.

Analysis showed it to contain, —

Inorganic matter	4.080	grains to 1 U. S. gallon.			
Organic and volatile matter	2.040		“	“	“
Total residue	6.120		“	“	“

The inorganic matter contained, —

Silica, alumina, oxide of iron, etc.	2.300		“	“	“
Chlorine	.870		“	“	“

An attempt was made to determine at the pond, the presence of free sulphuretted hydrogen, and its amount, if any were present, in the water of the upper Mystic ; but the results obtained were negative. The sample taken at a depth of 50 feet was as free from this gas as the surface water.

The foregoing analyses go to show — to a certain extent — what the character of the water in the lower basin would be, if the salt water were pumped out and its regress prevented, and time enough had elapsed for the decomposition of the organic matter deposited at the bottom. The two ponds lie in the same primitive basin, and there is nothing to lead us to suppose that after the salt water had been removed, and the ingress of sewage matter prevented, their waters would be essentially unlike.

I append to this report a synopsis of the results obtained with the waters of the lower Mystic (A) ; a chart showing the ratio of increase in the amount of total residue in the same (B) ; a graphic representation of the rate of increase of the sulphuretted hydrogen in the same (C) ; a schedule of the results of analyses of the various samples of mud (D) ; and one showing the results obtained with the upper Mystic waters (E). I am much indebted to Mr. J. H. Osgood, B. S., for

assistance in the determinations at the pond, and in reducing to a system the enormous mass of figures obtained in the analytical work. As I have given you, in advance of this detailed statement, the general conclusions to which I have arrived, I need not repeat them here.

Very respectfully yours,

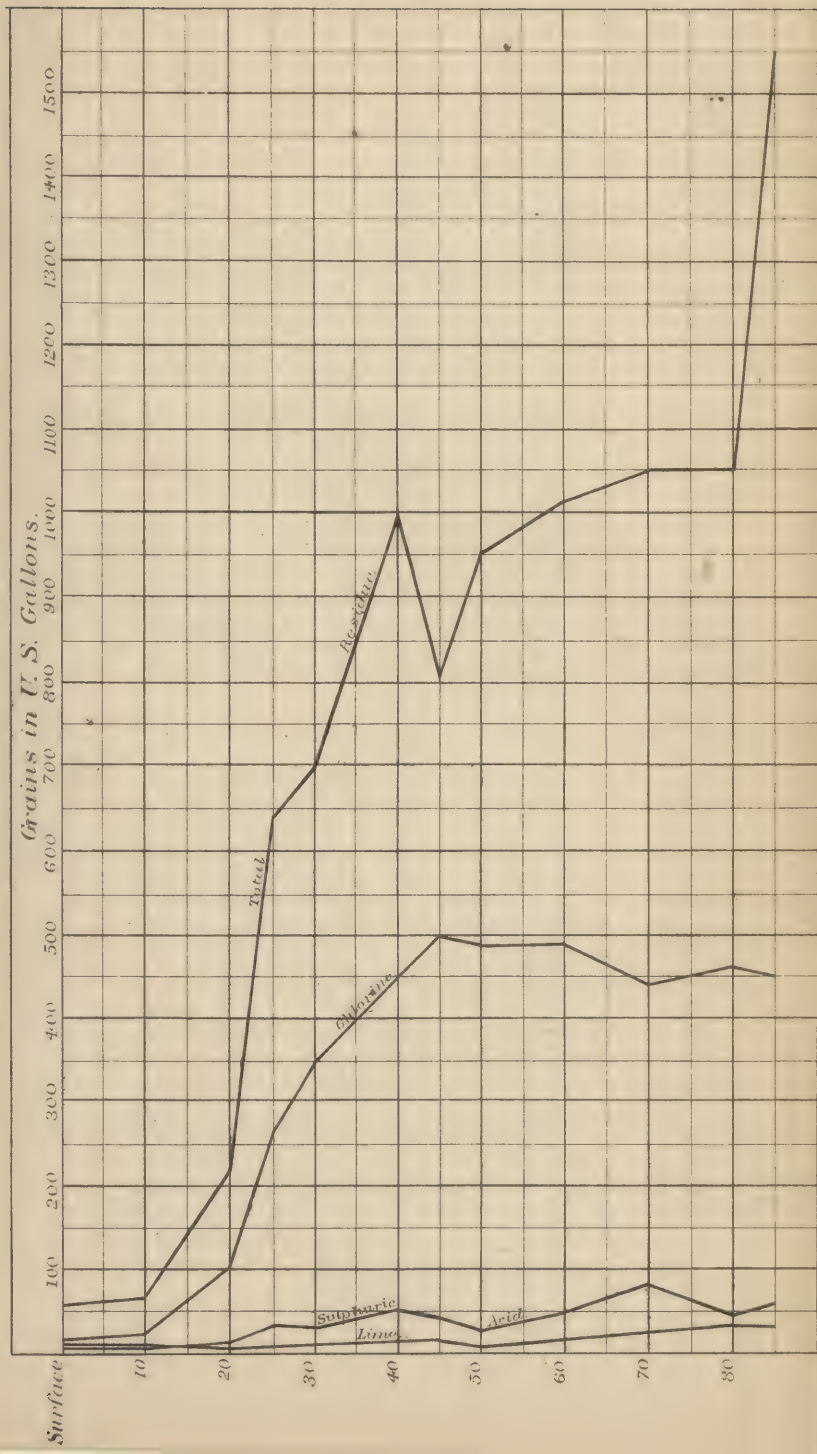
J. M. MERRICK,
Consulting Chemist.

RÉSUMÉ OF ANALYSES OF LOWER MYSTIC POND WATER, JULY, 1874.

Numbers.	Date.	Depth.	Taste and Odor.	Color.	Deposit.	GRAINS TO ONE U. S. GALLON.										Free Sulphuretted Hydrogen.	Combined Sulphurett'd Hydrogen.
						Inorganic.	Volatile and Organic.	Total Residue.	Chlorine.	Sulphuric Acid.	Silica.	Alumina, Oxide of Iron, and Phosphates.	Lime.	Magnesia.			
1	1874. July 27	{ Lower Mystic sur- face.	Slight.	Nearly colorless.	Trifling amount.	47.763	9.788	57.549	17.160	4.410	.292	1.163	4.192	.....	.....	.....	
2	" "	10 feet.	Faint brackish.	" "	" flocculent.	54.563	8.277	62.845	23.014	3.594	.058	.350	6.786	.....	.....	.....	
3	" "	20 "	" "	" "	Considerable.	199.755	28.452	228.207	104.820	13.756	.116	.876	6.058	15.209	.....	.....	
4	" "	25 "	{ Strong saline; strong odor of sulphuretted hydrogen.	" "	.....	538.678	98.154	636.832	278.927	37.989	.262	22.393	23.301	5.840	.....	.....	
5	" "	30 "	{ Strong saline; odor as 4.	" "	Deposits sulphur.	651.903	52.699	704.605	348.611	23.293	33.010	20.524	10.194	.....	.....	.....	
6	" "	40 "	{ Saline; strong odor of sulphuretted hydro- gen.	Yellowish.	{ Considerable; depos- its sulphur.	880.396	170.120	1000.466	457.607	52.738	9.340	.....	.....	.....	.....	.....	
7	" "	Upper end, 45 ft.	{ Strong saline; odor as 6.	Clear yellowish.	{ Slight; d'p'sits sulph'r on standing.	785.232	21.617	806.849	500.046	43.290	.408	63.683	16.143	3.416	.....	.....	
8	" "	50 feet.	" " "	" "	{ Some deposit; depos- its sulphur.	874.544	80.480	955.024	486.216	24.793	.116	2.220	10.398	19.220	.....	.....	
9	" "	60 "	" " "	" "	{ Flocculent deposit; otherwise as 7 and 8.	916.832	100.491	1017.293	491.347	42.988	1.517	18.578	15.298	12.156	.....	.....	
10	" "	70 "	" " "	" "	" "	910.820	139.648	1050.468	441.448	79.698	6.542	11.550	24.687	25.998	.....	.....	
11	" "	80 "	" " "	Yellowish.	{ Became dark brown and very offensive on standing 6 weeks.	925.685	127.950	1053.635	464.255	46.774	.876	.....	38.446	.....	.....	.....	
12	" "	80 "	{ Strong saline; faint odor, not of sulphur- ett'd hydrogen.	"	{ No offensive smell; no change of color af- ter standing 6 weeks.	917.441	119.771	1037.212	435.239	65.983	6.781	9.640	40.776	19.849	.....	.....	
13	" "	Lower end, 85 ft.	{ Strong saline; strong smell of sulphuretted hydrogen. Blackish, and turbid with sus- pended matter.	.....	.....	1356.440	210.330	1566.770 Of this, 419.772 is suspended matter.	388.480	49.667	Large amount	56.673	36.116	3.906	Cubic inches to one cubic foot, 140.610	Cubic inches to one cubic foot, 24.985	
14	" "	85 feet.	" " "	.....	.....	891.210	124.155	1005.365 Of this, 419.772 is suspended matter.	443.685	59.363	" "	150.268	35.650	3.651	.....	.....	
15	" "	{ Outlet of pond a little after low tide. Surface.	Slightly brackish.	Faintly yellow.	Little sediment.	51.414	38.561	89.975	22.545	9.012	.292	1.460	5.242	2.105	.....	.....	
16	" "	Upper end. Surface	{ Faint odor; brackish taste.	" "	" "	44.403	7.011	51.414	9.452	3.258	1.752	4.089	6.552	2.631	.....	.....	
17	" "	{ Outlet of Mill Brook.	{ Tasteless and inodor- ous.	Colorless.	.....	3.505	2.921	6.426	.449	.....	.....	With silica. .523	.....	.....	.....	.....	
18	" "	{ Outlet of pond lit- tle after high tide	Faint odor; brackish.	"	.....	47.616	11.685	59.301	21.306	5.647	2.044	3.145	9.465	1.444	.....	.....	

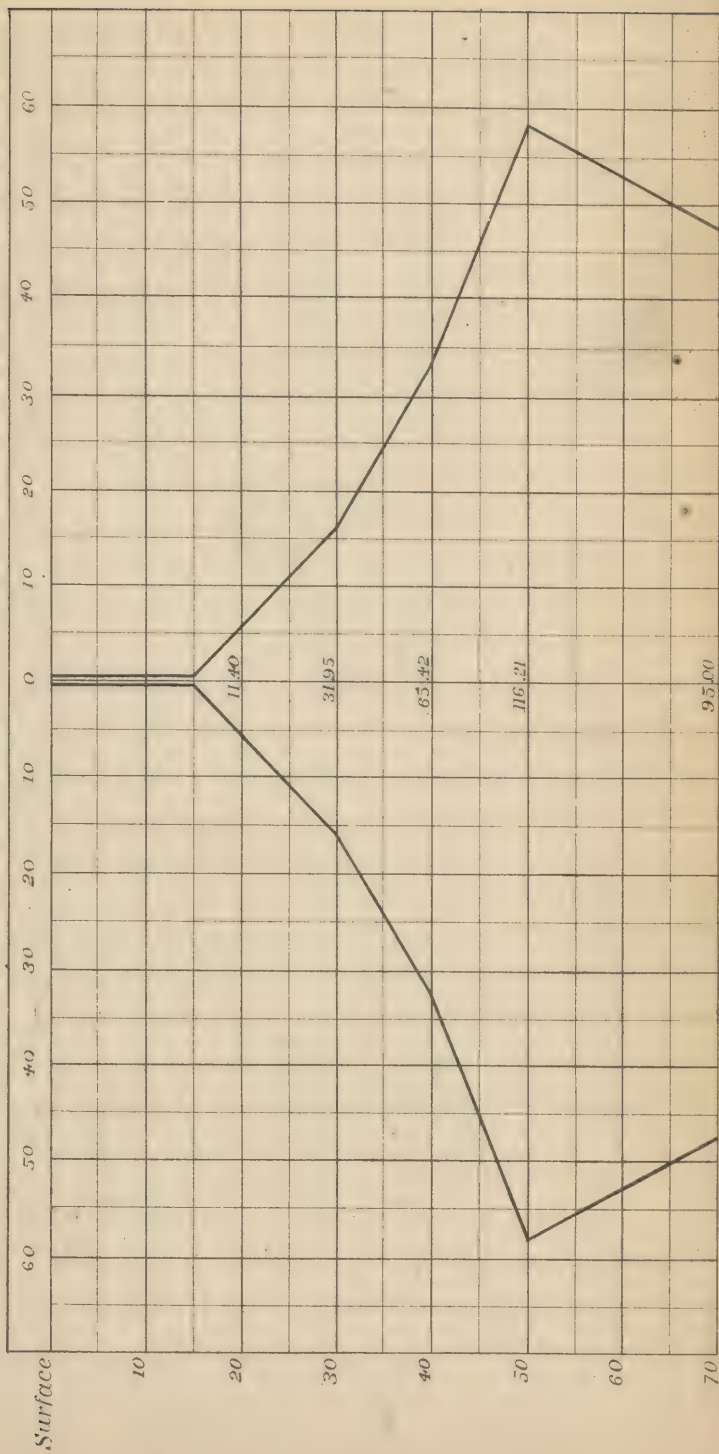
LOWER MYSTIC POND.

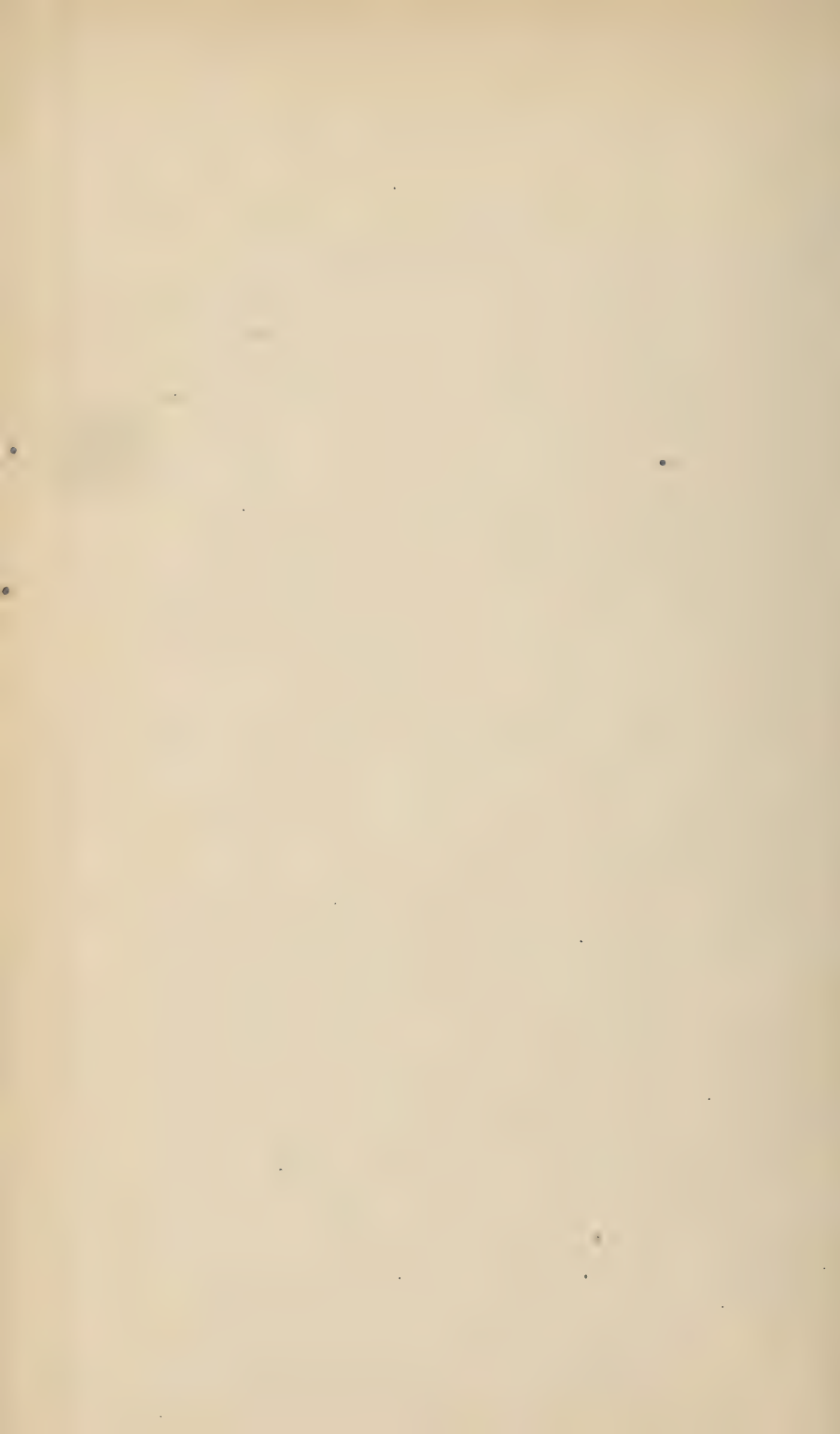
Profile showing the increase in total Residue, Chlorine, Sulphuric Acid and Lime from surface to a depth of 85 feet.



LOWER MYSTIC POND.

Diagram showing cubic inches of free sulphuretted hydrogen in a cubic foot of water from surface to a depth of 70 feet.





[D.]

RESUMÉ OF ANALYSES OF MUD-DEPOSITS FROM UPPER AND LOWER MYSTIC PONDS, AUGUST AND SEPTEMBER, 1874.

No.	Date.	Pond.	Depth.	Character.	Water.	Dry Residue.	DRY RESIDUE.		INORGANIC.			100 PARTS DRY MUD CONTAIN—				SULPHURETTED HYDROGEN. CUBIC INCHES TO 1 CUBIC FOOT OF MUD.			
							Inorganic.	Volatile and Organic.	Silica. Oxide of Iron.	Iron, Alumina, and Phosphates.	Chlorine.	Silica, etc.	Alumina, Iron, and Phosphates.	Organic and Volatile.	Chlorine.	Free.	Combined.	Total.	Ratio of Free to Combined.
1	August 4, 1874.	Lower Mystic.	35 feet.	Thin mud. Darkening Lead Paper at ordinary temp.	90.98	9.02	6.86	2.16	5.71		.147	68.30		23.94	1.63	Traces.	157.07	157.07	
2	" "	" "	40 feet.	Thin mud. Darkening Lead Paper at ordinary temp.	91.27	8.79	6.50	2.29	5.36		.228	60.97		26.05	2.59	"	224.41	224.41	
3	" "	" "	" "	Thick and offensive. Giving off Sulphuretted Hydrogen at ordinary temp.	86.11	13.89	10.96	2.93	9.31		.245	67.02		21.09	1.74	455.06	203.24	658.30	1 to .44
4	" "	" "	" "	Thin. Giving off Sulphuretted Hydrogen at ordinary temp.	90.02	9.98	8.00	1.98	7.04		.089	70.54		19.84	.79	149.61	33.21	182.82	1 to .22
5	" "	" "	65 feet.	Thin. Not very offensive	92.23	7.77	6.06	1.71	4.79		.317	61.64		22.00	4.08	Traces.	214.96	214.96	
6A	" "	" "	70 feet.	Thin. Somewhat offensive	88.33	11.67	9.39	2.28	7.81		.14	66.92		19.45	1.19	211.174	167.114	378.288	1 to .77
6B	September 7, 1874.	"	85 feet.	Strong odor of Sulphuretted Hydrogen	83.00	12.00	9.47	2.53	{ Silica. 7.82 }	.398	{ Considerable amount. }	65.16	3.31	21.08		Traces.	249.08	249.08	
7*	August 11, 1874.	Upper Mystic.	18 feet.	Not offensive	84.86	15.14	12.71	2.43	12.18	.393	.009	80.44	2.60	16.05		"	Traces.		
8†	" "	" "	58 feet.	Somewhat offensive	86.45	13.55	10.40	3.15	7.85	.185	Slight amount.	57.92	1.36	23.24		1.398	465.810	467.108	1 to 333
9‡	" "	" "	60 feet.	Somewhat offensive	88.41	11.59	9.58	2.01	8.80	.893	" "	76.19	3.38	17.34		Traces.	261.81	261.81	
10§	" "	" "	77 feet.	Thin and somewhat offensive	89.53	11.47	7.94	2.53	7.20	.48	" "	68.76	4.58	24.16		"	97.24	97.24	
11	September 7, 1874.	Upper Mystic, near Bacon's Bridge.	Shallow.	Gravelly. Not offensive	86.81	13.19	10.93	2.26	10.34	.405	Traces.	73.40	3.07	17.14		"	Traces.		
12	" "	Upper Mystic.	80 feet.	Not offensive	88.54	11.46	7.74	3.72	7.28	.289	Slight.	63.55	2.52	32.44		"	"		

* Northeast part of pond, 250 feet from shore.

† Taken from the northwest part of pond, 100 feet from shore southeast of E. Dwight's house.

‡ East part of pond, 150 feet from shore.

§ Centre of lower part of pond.

[E.]

RESUMÉ OF ANALYSES OF UPPER MYSTIC POND WATER, JULY—SEPT., 1874.

No.	DATE.	POND.	DEPTH.	CHARACTER.	TOTAL RESIDUE.	INORGANIC MATTER.	ORGANIC AND VOLATILE.	SILICA.	CHLORINE.
1 . .	July 27, 1874.	Upper Mystic.	Surface.	{ Colorless, Tasteless, } { and Inodorous. }	5.257	3.797	1.460	.233	
2 . .	Sept. 7, 1874.	Bacon's Bridge.	"		7.418	5.258	2.160	1.16	1.27
3 . .	"	At Dam.	"		5.842	3.505	2.337	1.30	1.05
4 . .	"	Middle of Pond.	"		6.718	4.893	2.829	1.927	
5 . .	"	"	10 feet.		5.841	3.797	2.044	1.197	1.37
6 . .	"	"	20 feet.		6.419	4.083	2.33	1.752	.974
7 . .	"	"	30 feet.		5.840	3.970	1.869		.807
8 . .	"	"	50 feet.		6.120	4.080	2.040	2.300	.870

Silica, Alumina, Oxide
of Iron, etc.

APPENDIX E.

REPORT

OF

MR. A. FTELEY,

UPON

CHARLES RIVER.

APPENDIX E.

OFFICE OF BOSTON WATER WORKS, ADDITIONAL SUPPLY,
SOUTH FRAMINGHAM, Sept. 26, 1874.

JOSEPH P. DAVIS, *City Engineer*:—

DEAR SIR: Having been instructed by you, early in July, to report upon the availability of Charles river as a source of water supply for Boston, I commenced the necessary surveys without delay; but the investigations have, from necessity, covered so much ground, that more time has been occupied than was anticipated, although the work has been prosecuted with energy by the engineers' corps of this department.

In the following report I have endeavored to give a condensed statement of the facts which have been ascertained, and to draw from them the proper conclusions. Approximate estimates of the cost (based upon the prices used in former estimates for other sources) of various schemes of works designed to convey the waters of the river to Chestnut-hill reservoir are also given.

Charles river rises in Hopkinton, above Milford; the main stream and its numerous tributaries (the most important of which are Chicken and Mine brooks, Mill river, Stop river, and Bogistow brook) flow through the following towns, viz., Hopkinton, Milford, Holliston, Ashland, Bellingham, Franklin, Wrentham, Walpole, Norfolk, Medfield, Medway, Sherborn, Dover, Natick, Needham, Dedham, West Roxbury, Newton, etc.

The elevation of Charles river is not sufficient, within a

reasonable distance from Boston, to allow of diverting its water by gravity into a conduit connected with Chestnut-hill reservoir. Above the point where the level of the river is proper for such a plan, *i. e.*, West Medway, the water-shed is somewhat smaller than that of Sudbury river above the site of the dams proposed for the latter stream, and a conduit from that point to Chestnut-hill reservoir would be about 24 miles in length.

It is, consequently, preferable to take the water at some point lower on the river, to secure a larger water-shed and a more economical plan of works.

The water-shed of Charles river above Rockville, in the town of Medway, covers an area of 87 square miles; above South Natick, it has an area of 150 miles; and above Newton Lower Falls, one of over 200 square miles. At the last named place, two-thirds only of the water-shed are available (unless the rights of mill-owners on Mother brook be bought out), as one-third of the river-flow is diverted at Dedham into that brook and Neponset river. Nevertheless, it may be said that at any point between Rockville and Newton Lower Falls, where it is found advisable to establish a pumping-station, the flow is large enough, with sufficient storage reservoirs, to give to the city an abundant supply of water.

In the first report on "Additional Supply of Water," Doc. No. 29, 1873, page 60, you estimate at \$3,150,000 the cost of a scheme of works to take the water at a point between Newton Upper and Lower Falls, of a capacity sufficient to convey to Chestnut-hill reservoir 50,000,000 gallons daily, and including "storage reservoirs in the river valley, engines at the lower dam, force-mains to conduct the water to a small receiving basin or chamber on the river bluff, and a conduit from the basin to Chestnut-hill reservoir." This location being practically the lowest on the river from which the water can be taken, it has been thought proper to make

an estimate of the same scheme based upon the results of the various surveys which have been made in that neighborhood since the publication of your report, with reference to the Sudbury conduit line, and during this investigation.

The cost has been found to be \$3,332,000.

To this amount should be added the cost of the additional work that it has been found advisable, since the publication of your report, to make at Chestnut-hill reservoir in connection with the Sudbury plan, making a total cost of \$3,554,000.

Cost of delivering 1,000,000 gallons, \$17 05.

Another plan, not very different from the last, has been examined with the view of reducing the pumping expenses; the pumping engines are supposed to be located at Newton Upper Falls, and connected by force-mains and by a conduit with Chestnut-hill reservoir.

Estimated cost, \$3,575,000.

Cost of delivering 1,000,000 gallons, \$16 07.

The storage room to be provided in connection with these plans can be secured, at about the same cost, by the erection of a dam, either at Newton Upper Falls, near Pettee & Co.'s mill, or at some higher point in the river valley. A few words in regard to the reservoir that would be formed by the Upper Falls dam, are in place here.

The river from that point to Charles river village, a distance of more than 10 miles along the channel, rises but little; about Dedham, there are some very extensive meadows, to flow which, unless to a considerable depth, might be objectionable. It is thought that if a reservoir were to be constructed at that point for storage purposes, its high-water mark should be established as high as the top of the dam at Charles-river village, thus giving an average depth of some 13 feet over the meadows at Dedham, and an area of nearly 3,000 acres of water surface.

To prevent the flooding of a part of Dedham it would be

necessary to construct two dykes; one across the valley of Mother brook, with the necessary overflow and sluices, and the other across the brook from Wigwam pond, which, with all the sewage of Dedham, could be diverted into Mother brook at a moderate cost. The Dedham-branch Railroad would be raised for 7,800 feet of its length; 17,200 feet of roads would be regraded, some extensive bridges raised; one factory would be destroyed, a number of dwelling-houses damaged; more than 4,000 feet of filtering gallery and pipe conduit and the pumping station belonging to the Brookline Water Works would be flooded; and the water privilege at Charles-river village would be destroyed. The total area to be taken, including some marginal land, would be about 3,300 acres, and the available contents of the basin, 7,500,000,000 gallons.

The surface of water in this reservoir would be above the level of a portion of Dedham village; just what effect the presence of the reservoir would produce upon the welfare and health of the place it is impossible to foresee; but it is evident that it would not be beneficial, and it is possible that damages might be claimed by the town in its corporate capacity. In the preceding estimates, however, no provision has been made for such damages. There are, consequently, some serious objections against the construction of this basin, but, as the question of its practicability might arise, I have thought it well to give it some study, and to delineate its principal features.

A less objectionable reservoir can be built higher up the river, as will be described in connection with another scheme; but it would be remote from the proposed location of the pumping station either at the Upper or Lower Falls, and the water, after having been purified by storage, would be conducted to the pumps, a distance of nearly 18 miles, in the natural bed of the river, where it would be

exposed to the liability of contamination, especially from vegetable matter.

You have already called attention (Doc. No. 29, 1873) to "the probability of filtration being required" if the water should be taken at Newton Lower Falls; and that in this case, or in the case of Newton Upper Falls scheme, filtration is necessary, seems to be the general view, since both Brookline and Waltham have built filtering galleries or basins through which their public supply is drawn. It is probable that this matter will be fully discussed by the commission lately appointed to investigate the comparative purity of the water from various sources; and, therefore, no extended remarks are needed here.

Two other plans have been studied, in which ample provision is made for securing a greater purity of the water and for maintaining it.

The first is as follows: To take the water at a point high enough on the river to avoid a number of the contaminating sources, and combine the advantage thus secured with that of a very large storage reservoir to aerate the water, and remove from it whatever elements of pollution it may already contain; the water to be taken directly from the basin and pumped into the conduit connected with Chestnut-hill reservoir.

The second plan includes a pumping-station at Newton Upper Falls, and extensive filter beds connected by a conduit with Chestnut-hill reservoir.

Excellent storage basins may be formed in the upper part of the water-shed of Charles river, by throwing dams across some of its tributaries, and by improving some of its natural ponds. A reservoir should be built, however, at or near the point where the water is diverted from the river bed; but the topography of the valley is such that none but very large ones can be constructed near the more desirable sites for a pumping-station; it has therefore been thought proper to dis-

regard the smaller ones that might be built high up the valley, and to consider the lower one only, which would be of more than sufficient capacity to provide all the supply needed, and in which the water would be submitted to the purifying process of storage before reaching the pumps.

A location about one mile above South Natick has been selected as the best for the site of a dam; its distance from Chestnut-hill reservoir is not excessive; a capacious reservoir can be formed above it, and the water there would be much freer from pollution than it is at Newton Upper Falls, where it will contain the additional drainage of Natick, Wellesley, Charles-river village and Dedham.

The water-shed of the river above South Natick covers an area of about 150 square miles, and would, consequently, in a dry year, with sufficient storage-room, supply a daily average of over 80,000,000 gallons. The capacity of the proposed reservoir is made much larger than necessary to secure a flow of 50,000,000 gallons daily, because it cannot be determined in this case, as is usual, by the amount of water to be consumed, but by the requirements of the grounds. A short description of the proposed reservoir is necessary to substantiate this statement.

The rise of the river from the top of the present mill dam at South Natick to the next privilege in Rockville (Medway), a distance of over 14 miles along the river, has been found to be, on an average, only three and a half feet; hence the flowage must extend to that point, at least. For the whole of that distance the river flows, as shown by the accompanying map, through a very wide valley, mostly occupied by the extensive "Medfield meadows." The idea of freeing these meadows from the accumulation of vegetable matter on their surface cannot be entertained, on account of the magnitude of such an undertaking; but to destroy the influence of that vegetable matter upon the quality of the water stored, the

depth over it should be considerable, sufficient, even when drawn down during the summer, to prevent vegetation.

For the above reasons, the high-water mark has been established 122 feet above mean high tide, *i. e.* at the height of the top of the second dam in Rockville, or 15 feet above the present dam at South Natick; this would give a fair depth of water over the meadows, it being on an average, for the whole basin, 9.08 feet.

The southern end of this reservoir will have two branches extending about equal distances on Charles river and on one of its most important tributaries, Stop river.

The valley occupied by the proposed basin is but little inhabited, the town of Medfield, on its right bank, being the only village in its immediate vicinity.

The area to be taken, including a narrow margin around the high-water line, is equal to 4,416 acres, of which —

2,057 are wet meadows or swampy woods.

1,100 are brush, woodland and pasture.

500 are arable land.

The rest being grass land, with a small proportion of cranberry meadows.

The extreme length along the river is . . .	14.35 miles.
“ “ “ in direct line is . . .	9.55 “
“ “ width is . . .	2.06 “
The total perimeter of the water area . . .	66.63 “

Three hundred and fifty-four acres will be covered with not more than five feet of water.

To construct it, 14 bridges must be raised, 5.15 miles of roads must be regraded, and 2.32 miles of track raised on the Mansfield & Framingham Railroad and on the Woonsocket division of the Boston & Erie.

The damage done to property other than the land flowed, is as follows: four water privileges are destroyed, some others are more or less affected; a few farm buildings are

partially flooded, and some farms are injured by the taking of a part of their best land.

It is said above that the dam of this reservoir has been located about a mile from South Natick; the spot selected for that purpose is very favorable for its construction; the river banks are steep and rocky, and the soundings show that hard bottom can be reached on almost the whole of the line. The extreme length is 600 feet, of which one-quarter is not over five feet in height; the overflow is 250 feet long.

The consequences of an accident to a dam holding such a large body of water would be so disastrous, that its strength and durability must be secured beyond all possibility of failure; it is designed, accordingly, to be founded on the solid rock underlying the bed of the river, and to be built entirely of substantial masonry; large sluices are provided to control the flow of the river and to regulate the water supply.

The connection between the reservoir and the pumping-engines is established by an aqueduct seven feet four inches in width, with a fall of two feet per mile. The line of the aqueduct, 16,000 feet in length, runs along the left bank of the river as far as South Natick, follows then one side of Elliot street for 2,160 feet, crosses Waban creek near the Sudbury conduit line, and stops nearly half a mile beyond it, at the proposed site of the pumping-station, near the Ridge-hill road. The pumping-engines are four in number, each of a capacity of 17,000,000 gallons per day. From the pumps the water is conveyed through force-mains into a receiving-chamber located on the line of the proposed Sudbury aqueduct, which, from the receiving-chamber to Chestnut-hill reservoir, is adapted for this scheme, without change either of grade, size or direction.

The total length of the line of works from the South-Natick dam to Chestnut-hill reservoir is 58.456 feet, or 11.07 miles.

The estimate of cost for works of a capacity to deliver a supply of 50,000,000,000 gallons is : —

Reservoir and dam at South Natick, including land damages	\$1,273,882
Aqueduct from dam to pumping-station, including land damages	456,175
Four compound engines, capacity 17,000,000 gallons	360,000
Engine-buildings and foundations, wells, etc.,	260,000
Force-mains and receiving wells	55,000
Aqueduct from pumping-station to Chestnut-hill reservoir, including land damages and work at Chestnut-hill reservoir	2,271,620
	\$4,676,677
Superintendence	230,000
	\$4,906,677

The cost of delivering 1,000,000 gallons is as follows : —

Interest upon cost of works at 6 per cent.	\$294,400
Yearly cost of pumping, lift 37 feet	69,900
Cost of delivering 18,250,000,000 gallons	\$364,300
Cost of delivering 1,000,000 gallons	\$19 96

Two pumping-engines and the corresponding force-pipes might be dispensed with at present, and the cost reduced to \$4,709,177.

An estimate has been made for a scheme of works which might be mentioned as a substitute for the last, and would be somewhat cheaper.

The plan is as follows : —

To construct a dam at Greendale avenue, above Dedham, forming from that point to Charles-river village a reservoir covering 550 acres and holding 1,000,000,000 gallons ; to convey the water from that reservoir to a pumping-station

located on the left bank of Charles river opposite Newton Upper Falls, through a conduit built along the river bank, and to pump the water therefrom across Charles river into a conduit extending from Newton Upper Falls to Chestnut-hill reservoir.

This scheme would cost \$300,000 less than the last, but is not recommended on account of its presenting some objectionable features, namely :—

The new reservoir not being large enough, the South Natick basin cannot be dispensed with ; consequently, two extensive dams must be maintained instead of one ; the lift of the pumps is increased by some 12 feet, and the river water, after having been submitted to storage in the upper reservoir, must be conveyed to the lower in the natural river channel, where it will receive the sewage of Natick (if diverted from Lake Cochituate), South Natick, a part of Grantville, Wellesley, and Charles-river village.

FILTERING SCHEME.

The only practicable way of filtering regularly so large a quantity of water as is necessary for a city of the size of Boston, is to distribute it over gravel and sand beds artificially formed, and to let it percolate through those materials ; it is freed in this manner of all the particles kept in suspension, and reaches the clear-water reservoirs connected with the filters in an improved condition. Experience has shown, however, that very large filtering surfaces must be provided, as the water, to be thoroughly purified, must be drawn very slowly through the sand and gravel.

The filtering works established in this country in connection with the water supply for cities are few in number and comparatively unimportant ; therefore, the necessary information in regard to filtration on a large scale must be had from European practice.

When the waters to be filtered contain a large proportion

of sediment, it usually becomes necessary, before distributing them over the filtering beds, to allow them to settle in large basins where the heaviest portion of the sediment is precipitated to the bottom. As the waters of Charles river are never very turbid, the large storage reservoir to be constructed at South Natick will perform the functions of a settling reservoir.

Although much information is to be had on the subject of filtration from European practice, some points are left in doubt. Where the filtering process is used on a large scale, the winters are not generally so severe as they are in Boston, and, with additional care during the cold season, the filter beds are kept in working order. In Berlin and Altona, where the climate is probably as severe as ours, the filtering basins are not injured by the ice, which is kept carefully separated from the walls, but it is impossible then to clean the beds; fortunately for the above cities, the water supplied by the streams is very clear in winter time, and as no cleaning is required for a long period, the water supply is not interrupted.

Experience alone can show whether the water of Charles river would be, in winter time, as free from impurities, and whether the sand beds would pass the necessary amount of water for a long period without being cleaned; but, if the condition of the water were generally such that the beds should be cleansed regularly during severe frosts, then the filters should be roofed in. This would involve a large expenditure, which has not been taken into account in the estimate of cost.

The dimensions adopted for the proposed filter beds are 300×150 feet, and, from comparison with other works, it is found that 16 beds are necessary to supply daily 50,000,000 gallons; 13 of them would be in operation and three disconnected for cleansing or for repairs.

As, besides the filter beds, two reservoirs are needed, one

to receive and distribute the unfiltered water, the other to collect the clear water, a very large area is required for their construction; moreover, the land must be found at a convenient elevation. Therefore the location of the whole line of works is to be governed by that of the filters.

They have been located near Newton Highlands, on a plot of land enclosed between Woodward street, the Cochituate aqueduct, and the Sudbury conduit line, the unfiltered-water reservoir only being placed on the other side of Woodward street.

The water is taken from the river between the two water privileges in Newton Upper Falls, and a dam 10 feet high is thrown across the river where its bed is narrow and rocky, thus forming a small reservoir; the water privilege situated above would consequently be deprived of a large part of its fall.

The pumping-engines, connected with this reservoir by a short brick conduit, are located some distance north of Boylston street, near the bank of the river, and send the water through force-mains and another brick conduit into the unfiltered-water reservoir; from this it is distributed over the sand beds.

The filtering basins are enclosed by vertical walls of rubble masonry, with concrete and brick bottoms; they are symmetrically disposed on each side of a central line, and are connected by the necessary gates and channels with the filtered-water reservoir. An aqueduct starts from the latter, and, after a short distance, meets the line of the Sudbury conduit, which it follows to Chestnut-hill reservoir, a distance of nearly 12,500 feet.

The total length of the line, exclusive of the filters, is 17,600 feet (3.31 square miles).

In addition to the above, a sewer has been devised to divert into the river, below the proposed dam, the drainage of Newton Upper Falls and of Newton Centre.

The estimate of cost for works of a daily capacity of 50,000,000 gallons is as follows : —

Dam, gate-house and conduit to the pumps, including damage to water privilege . . .	\$133,000
Four 17,000,000 gallons pumping-engines, lift 78 feet	520,000
	\$653,000
Foundations and buildings	\$300,000
Force-mains and receiving well	115,000
Brick conduits, including sewer at Newton Upper Falls, work at Chestnut-hill reservoir and land damages	1,088,193
Superintendence	270,000
Filters and reservoirs, including land damages	1,666,164
Storage reservoir above South Natick	1,273,882
	\$5,366,239

The cost of delivering 1,000,000 gallons is as follows : —

Interest upon cost of work at six per cent . . .	\$321,974
Yearly cost of pumping and filtering	139,660
Cost of delivering 18,250,000,000 gallons . . .	\$461,634
Cost of delivering 1,000,000 gallons	\$25 30

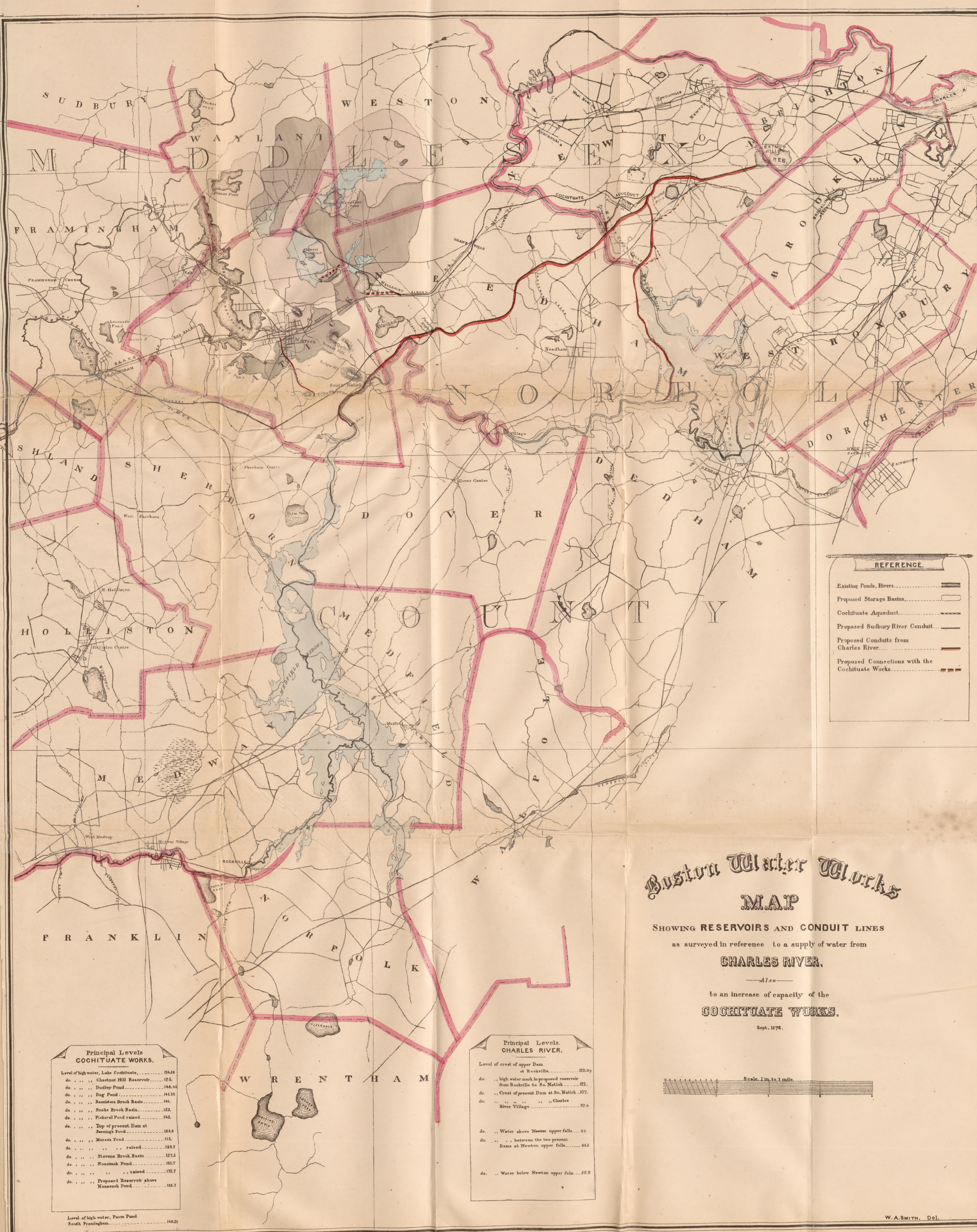
The cost of works proportioned for immediate use, with two pumps only and four filter beds, is \$4,109,409.

It has been said that no subsiding reservoirs can be conveniently constructed in direct connection with the filters; one basin, of a capacity of 100,000,000 gallons, can be built, however, below Newton Upper Falls in the valley of the river, and the water pumped directly from it; but, owing to its size, and to the fact that the stream of the river would pass through it, it is questionable whether the settling process could take place successfully; it has been thought that

the doubtful advantages to be derived from it would not be an adequate compensation for the following objectionable features of this plan, viz. : The line of the works is longer ; the sewer intercepting the drainage of Newton Upper Falls and Newton Centre must be lengthened ; the dam to be constructed is much more expensive ; the lift of the pumps is increased by 10 feet, and the difference of cost is about \$250,000 in favor of the plan described above.

Respectfully submitted,

A. FTELEY,
Resident Engineer.



REFERENCE.

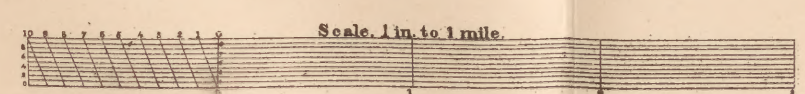
- Existing Ponds, Rivers.....
- Proposed Storage Basins.....
- Cochituate Aqueduct.....
- Proposed Sudbury River Conduit.....
- Proposed Conduits from Charles River.....
- Proposed Connections with the Cochituate Works.....

Boston Water Works MAP

SHOWING RESERVOIRS AND CONDUIT LINES
as surveyed in reference to a supply of water from
CHARLES RIVER.

—Also—
to an increase of capacity of the
COCHITUATE WORKS.

Sept. 1874.



**Principal Levels
COCHITUATE WORKS.**

Level of high water, Lake Cochituate.....	154.26
do. „ Chestnut Hill Reservoir.....	125.
do. „ Dudley Pond.....	146.46
do. „ Dag Pond.....	141.56
do. „ Bannister Brook Basin.....	141.
do. „ Snake Brook Basin.....	153.
do. „ Pickers Pond raised.....	143.
do. „ Top of present Dam at Janning's Pond.....	128.8
do. „ Morse's Pond.....	115.
do. „ „ „ raised.....	120.5
do. „ Stevens Brook Basin.....	127.5
do. „ Nonesuch Pond.....	165.7
do. „ „ „ raised.....	175.7
do. „ Proposed Reservoir above Nonesuch Pond.....	185.7

Level of high water, Farm Pond
South Framingham..... 149.25

**Principal Levels.
CHARLES RIVER.**

Level of crest of upper Dam at Rockville.....	122.09
do. „ high water mark in proposed reservoir from Rockville to So. Natick.....	122.
do. „ Crest of present Dam at So. Natick.....	107.
do. „ „ „ „ Charles River Village.....	97.4
do. „ Water above Newton upper falls.....	82.
do. „ „ „ between the two present Dams at Newton upper falls.....	66.5
do. „ Water below Newton upper falls.....	56.2

W.A. SMITH. Del.